Systems Assessment of New Technology: International Perspectives

Excerpts from a IIASA Workshop
July 18-22, 1977

G.M. Dobrov, R.H. Randolph, and W.D. Rauch, Editors

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PREFACE

One of the important functions of IIASA is to hold workshops and conferences on subjects of recent and developing importance relevant to applied systems analysis so as to obtain an international exchange of views and information among experts in the field. The assessment of new technologies on an international basis is certainly one of these subjects. Whereas up to now, technological innovation has enabled us to increase our standard of living over the last decades, we now rely on continuing innovation as our main hope of maintaining the standard of life that certain parts of the world have achieved and to which the wider world now aspires. It was with these thoughts in mind that IIASA's Management and Technology Area organized the Workshop on Systems Assessment of New Technologies: International Perspectives (July 18-22, 1977).

The belief that this was an important and potentially useful subject was confirmed by the attendance at the Workshop: more than 60 participants from 17 countries (including both Council for Mutual Economic Assistance and Organisation for Economic Co-operation and Development member states) and 5 international agencies, representing many fields of interest. The topics covered at the Workshop included the dynamics of technological change, technology management, and technology forecasting and assessment, all studied within the broad approach of the applied systems analyst.

When I came to discuss the question of publication with Gennady Dobrov, who was responsible for planning the Workshop, we found ourselves in a quandary. Some general statement on the current state of the art seemed to be needed, and it was clearly desirable to make some of the material given at the meeting more generally available. On the other hand, publication of the full proceedings would have duplicated much material available elsewhere, as well as requiring a volume that would have been unapproachable, if only because of its size, by the interested reader.

The present volume therefore selects a number of papers by leading proponents of technology assessment and gives their views on the main findings to be obtained from the Conference. It therefore provides a much needed summary of the state of the art as seen by Gennady Dobrov and his colleagues up to the end of 1978.

The editors and authors would like to offer special thanks to the many individuals at IIASA who contributed to the preparation of the Workshop and these proceedings.

Rolfe Tomlinson
Area Chairman
Management and Technology

ABSTRACT

This volume presents a selection of papers from a IIASA workshop concerned with international perspectives on the problem of systems assessment of new technology. These papers examine both common and unique features of national experiences in this area, review some methodological findings and practical applications, and discuss some promising paths for further investigation in the field.

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Toward Effective International Technology Assessments

K. Chen and L. Zacher

INTRODUCTION

Technology assessments (TAs) are policy oriented systematic studies of the social impacts and the social management of science and technology (ST). With its increasing power, scale, and complexity, technology and its impacts respect no national boundary. Earth-orbiting space satellites launched by one country can gather information about all countries. Carbon dioxide and fluorocarbons released from one geographical region can have long-term effects on global climate. Nuclear technologies developed by one nation may be improved and applied by another. There are natural resources, such as those of the Antarctic, that should be developed and utilized to the benefit of the world through appropriate international collaboration, using technologies that would not cause undue damage to the environment.

Thus, the use of earth-orbiting satellites, international environmental issues, global search for new sources of energy, exploitation of new resources in the Antarctic, in the oceans, in the planets, or in outer space, international transportation problems, the danger of manipulating people and societies with the help of ST (medical, biological, chemical, military, electronic, and communication technologies), etc., are important subjects, not only for philosophical and ethical considerations, but also for policy-oriented international assessments of technology. Removal of the specter of nuclear holocaust and achievement of worldwide disarmament are not just political issues, for in the course of their practical resolutions, the broad and long-range consequences of powerful military technologies must be carefully assessed.

In addition to the avoidance of global disasters resulting from the misuse of science and technology, international TAs are also necessary in some constructive activities. A case in point is technology transfer among nations, which has been mostly commercial in character, and only occasionally in the form of technical assistance via bilateral or multilateral arrangements. However, technology transfer, especially to the Third World countries, has been traditionally considered mainly on the basis of technical and economic feasibility. This has resulted in certain undesirable cultural side effects of technology transfer, such as technological overdependence on foreign countries, uprooting of the rural unemployed and their migration to the urban ghettos, mismatch between the demand for skilled factory workers and the supply of theoretical scientists, and the intellectual brain drain [1,2]. International TAs are needed that will carefully analyze the value systems, societal goals and political and cultural possibilities in both the technology-transmitting and the technology-receiving countries, so that appropriate technologies can be developed and adopted by the Third World countries.

National science and technology policies cannot be made without international considerations, cooperation, and coordination. Frequent international meetings of science ministers of various countries, both in the East and in the West, have taken place over the past decade.* TA, intended to provide useful information for technology policymaking, has acknowledged at its formative stage the importance of its international aspect. The name of the International Society for Technology Assessment (ISTA), which is probably the only existing professional society in this field, testifies to this acknowledgment. To date, ISTA has held two international congresses and a number of conferences in various countries, facilitating the exchange of ideas and experiences among the users and doers of TA from many OECD, CMEA, and Third World countries.** While these exchanges have made possible the sharing and comparison of TA methodologies and experiences in various *individual* countries, no fully fledged TA project has been attempted, nor will it be likely, in the near future, to involve an international team of professionals working on a substantive problem of international or global significance, with the intention of providing serious inputs to the technology policymakers in the countries involved. This is especially true for projects that would involve both Eastern and Western countries, in spite of the need for international TAs in such areas as satellites, nuclear power, and the Antarctic, as mentioned previously, which will require international collaboration, especially between the East and the West.

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*For example, under the auspices of the Organisation for Economic Co-operation and Development (OECD), five meetings have been held of the Ministers of Science of the 24 industrialized, market-economy nations of Western Europe, the USA, Canada, Japan, Australia, and New Zealand. These meetings have been prepared by a standing committee concerned with scientific and technological policy issues which reports to the OECD Council, which is made up of the permanent Heads of National Delegations to the OECD. Similar meetings were organized in the 1960s by UNESCO. Within the Council for Mutual Economic Assistance (CMEA) is an active special commission for scientific and technological cooperation.

**The First International Congress on Technology Assessment was held at The Hague, Netherlands, in May 1973; the Second International Congress on Technology Assessment was held at Ann Arbor, Michigan, USA, in October 1976.

THE CONTEXTUAL DIMENSION OF TA

It has been said that science is an international language. This is true to the extent that all physical and natural scientists, irrespective of their nationalities, by and large use the same basic methods for scientific inquiries. Although TA is still a relatively new field, the basic methods used by its practitioners from different countries appear to be rather similar, inasmuch as they generally apply systems analysis approaches to provide interdisciplinary linkages for engineering, economics, cybernetics, sociology, law, and other relevant branches of knowledge [3]. Thus, at first glance, the internationalization of TA appears relatively easy. A more careful examination of the ultimate purpose of TA, however, leads to a less sanguine conclusion. This is because of the policy orientation, which puts TA in a larger and more complex social context than pure science.

First of all, a commonality of methods does not necessarily imply a commonality of methodologies, which are particular combinations of the component methods for doing TA in such a way that the results are useful to the policymakers. Each set of selected methods constitutes a methodology [4]. The appropriate choice of a methodology depends on the policymaking process through which a substantive problem is solved (or through which a substantive issue is resolved). An effective TA is accomplished only if the methodology, the policymaking process, and the substantive implementation are all mutually compatible within the context of a set of basic premises. Figure 1 shows conceptually this contextual embedding for effective TA. The total embedding shown represents only an ideal situation; the basic premises of TA include the cultural image of technology in society and the expected role of TA in policymaking. The substantive problem is also embedded in the basic premises, as in Figure 1, since the definition of any substantive problem and its relative significance are culturally dependent.

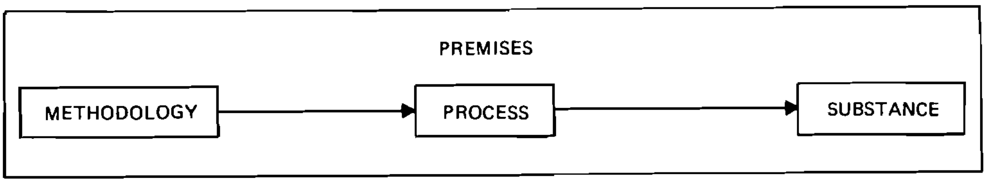

Figure 1. Effective TAs are predicted on the compatibility among methodology, processes, and substance embedded in the context of a set of basic premises.

TA will not be effective if the methodology, the process, and the substance are not embedded in the same basic premises. An example is the nonutilization of TA when the doers and the users, living in different cultures or subcultures even in the same country, do not share the same premises underlying TA [5]. Figure 1 should be interpreted with flexibility. TA can still have some effectiveness even if the methodology, the process, and the substance are not totally embedded in the same premises. Moreover, basic premises may be changed and shared through communication and interaction among people in different cultures; this is usually the real situation.

The concept in Figure 1 suggests that international TA is more difficult than TA conducted by a single nation, because international TA, to be effective, must deal with multifarious policymaking processes and divergent premises. The degree of divergence increases as the cultural distance among the nations involved in the international TA increases. The efficacy of TA, already plagued by the epistemological distance among various disciplines [6] in ordinary cases, is further weakened by the cultural distance among different nationals when it is internationalized.

Searching for an effective international (TA) methodology does not necessarily mean the acceptance of a single or a completely unified approach. Starting from very simple basic assumptions, we can expand and then decompose our approach, considering various parameters that will modify and affect the primary general approach. Let us consider some examples of such parameters. Table 1 shows the implications of considering the time-horizon parameter. The dynamics of most technological processes are such that effective international policy actions in the short run will be oriented toward stopping some harmful technologies (by international agreements of the nuclear test-ban treaty type); that those in the medium run will be oriented

Table 1.

Orientation of TA Results	Time-Horizon			Type of International Cooperation in Implementing TA Results
	Short	Medium	Long	
Stopping technology	x			International agreement
Substituting technology		x	x	Technology transfer
Developing technology			x	Cooperation in long-term R&D projects

toward substituting current technologies in one country by borrowing and adapting technologies from another country; and that those in the long run will be oriented toward developing new technologies, fulfilling internationally accepted goals on the basis of scientific and technological cooperation (via long-term research and development (R&D) projects, involving a number of nationals leading to "programmed" desirable technologies).

Another important parameter will be the sociopolitical and institutional system of the countries involved in international TAs. There is a feedback path especially in the long run, which links the use of ST in a society to its societal goals as determined by its sociopolitical system. In international TAs involving countries with very different systems (e.g., market economies and centrally planned economies), extra efforts must be made to prepare a set of common criteria for assessment (e.g., on the basis of the United Nations' agreements) and to set up a set of common (or at least mutually understood and accepted) decision and implementation mechanisms. The sociopolitical and institutional parameters are very important because they determine not only the goals but, to a greater extent, the mechanisms of their realization. In other words, a general approach would have severe limitations without this specific consideration.

Still another important parameter that ought to be considered in international TAs is the level of economic, technological, and political (methods and styles of decisionmaking) development in the participating countries. Generally speaking, the stage of development determines, at least in the short and medium runs, goals and tasks as well as the mechanisms of their implementation. Idealistic goals of technological development will not be very meaningful where poverty and scarcity of resources exist, since a narrow range of economic alternatives would in turn severely limit technological choices. On the other hand, with affluence and availability of resources, a broad range of economic and social alternatives are possible, and so will be the technological means for goal realization. International TAs can be effective only if the involved parties are fully aware of these differentiating parameters.

Although no two countries have identical premises and processes of TA, there are elements of similarities as well as differences. At the outset of the present paper examples are given of substantive problems of common concern to many countries. If effective international TA is to be accomplished, the elements of similarities and differences in the premises and processes of TA in the collaborating countries must be identified before a meaningful and effective methodology can be developed. Figure 2 shows how effective international TA can be accomplished by emphasizing similarities and by understanding the differences between countries. As suggested by the diagram, effective methodologies could be developed on the basis of the elements of similarities in premises and processes even though there may be many elements of difference.

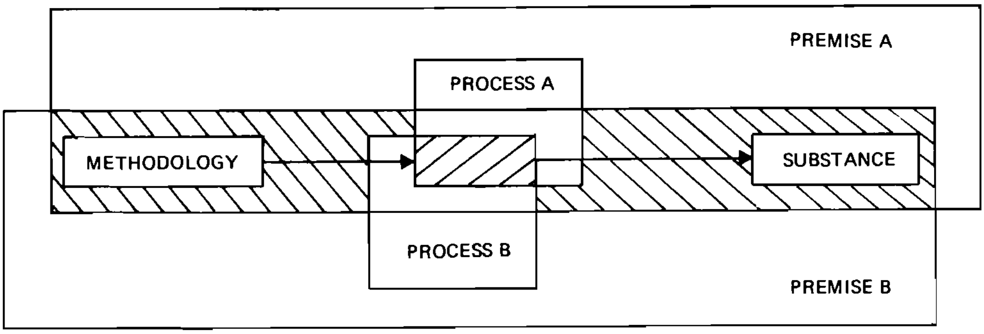

Figure 2. Common methodology can be developed for international TA of common substantive problems by emphasizing the elements of similarities in premises and processes.

EXAMPLE OF CROSS-NATIONAL COMPARISON

To illustrate what we mean by similarities and differences in TA premises and processes, we will make a preliminary cross-national comparison between typical OECD countries and typical CMEA countries.* We do this comparison with the belief that any significant problems, such as those mentioned previously, can be solved only if there are effective international TAs involving both OECD and CMEA countries. We do this as a first step toward a more comprehensive cross-national comparison, as we recognize that there are important differences between OECD countries [7] and between CMEA countries, and that Third World countries must also be involved in international TAs.

A central element of similarity in TA premises of OECD and CMEA countries is that technologies with broad social implications should be brought under social control. The philosophical assumptions underlying TAs are recognized by researchers in OECD countries as in contrast with the traditional laissez faire attitude toward technological development [8]. In CMEA countries, TA has been viewed as a basis for the effective management of science and technology, again in contrast with the traditional laissez faire attitude toward science and the traditional belief that science is unmanageable [3]. In OECD countries, TA has been associated with the historical trend of increasing intrusion of public concerns in the practice of the engineering profession [9]. Because of their demand on limited resources, even the

*The comparison has been based on a cursory review of the literature and a brief working relationship between the authors. An in-depth analysis is in order for any serious international TA.

immense success of science and technology has led to the political problem of how to guide and manage technological progress for the well-being of society [10]. The social management of technology, which has long been a practice in centrally planned economies [11,12], is becoming an increasingly accepted concept in OECD countries.*

Despite these similarities, there are significant differences in TA premises between the OECD and CMEA countries. In the former, TA, in identifying the consequences of technological developments which would be valued differently by different social groups, has become a vehicle to reflect diverse social values in political debates on technology policy. In the CMEA countries, TA has become a tool for efficient technology management within the framework of a central plan that reflects certain social values [3,13,14]. This difference probably manifests a deeper dichotomy between historical determinism (in a stochastic rather than mechanical interpretation) [15], and the image of man as a free being capable of choosing his destiny among a wide range of alternative futures [16].

The policymaking processes within which TA must operate have similarities between the OECD and the CMEA countries. For example, large-scale technological developments such as space exploration and nuclear power are largely under the control and regulation of national governmental agencies. The two-communities theories that TA doers and users live and operate in separate worlds with different and often conflicting values, different reward systems and different languages [5] probably have equal validity in explaining and predicting the difficulty in effective use of TA in real policymaking in both OECD and CMEA countries. Finally, the absence of a powerful international governing body with the authority to legislate and enforce international laws makes international TA equally difficult in this respect for all countries.

The major difference in policymaking processes with respect to TA lies in the fact that most technological initiatives and decisions in the OECD countries lie within the private sector whereas this is not the case in the CMEA countries. Internationally, the multinational corporations play a significant though controversial role in technology transfer and resource flow to and from OECD countries [17], but only a minimal role in CMEA countries. As a result of the difference in the basic premises discussed previously, value conflicts in TA are frequently visible in OECD countries through open adversary processes [18], whereas similar cases are usually handled through central planning and social debates and consultations in CMEA countries [19].

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*For example, the University of Washington (Seattle) has a program in the Social Management of Technology.

The above similarities and differences are given in Table 2. We maintain that, while we should emphasize the similarities in the development of effective international TA methodologies, we should also be aware of, and be sensitive to, the differences in order to avoid unnecessary complications. Moreover, the differences could also provide an opportunity for mutual learning. For example, the experience of OECD countries in dealing with diverse goals and values in TA would be helpful when there are conflicting goals and values between countries participating in international TAs. On the other hand, the experience of CMEA countries in normative TA can be exploited once sufficient agreement on some specific goals and criteria for an international TA is reached.

Table 2. Elements of similarities and differences in TA premises and processes between OECD and CMEA countries.

	PREMISES	PROCESSES
SIMILARITIES	• Reduced laissez faire attitude • Social management of technology	• National government controlling large-scale technology • Two-communities theories in TA utilization • No international government
DIFFERENCES	• Divergent versus certain social values • Alternative futures versus historical determinism (stochastically interpreted)	• Role of the private sector • Role of multinational corporations • Open adversaries versus social debates and consultations during planning process

AN AGENDA FOR FUTURE WORK

The above example is no more than a beginning of a cross-national understanding of TA premises and processes, an understanding that we believe to be a prerequisite for effective international TAs. What steps could be taken toward the development of useful methodologies and the establishment of effective institutions for international TAs? We propose a 10-step agenda for possible future work, as follows:

1. Establish an in-depth cross-national understanding of TA premises and processes for two or more countries or groups of countries;

2. Develop a tentative common methodology for international TA involving these same countries, agreeing especially on the treatment of diverse values, uncertainties, and project integration;

3. Select a pertinent substantive area for international TA involving these countries;

4. Conduct a pilot TA project and learn from the experience;

5. Conduct a full-fledged TA project using, if necessary, a modified and improved common methodology;

6. Conduct international TAs in other substantive areas involving the same countries;

7. Repeat, or conduct in parallel, the above steps for a different set of countries;

8. Generalize and modify international TAs involving the union of sets of countries;

9. Update step 8 on a continuing basis;

10. Institutionalize international TAs [20].

This agenda represents but one of many possible approaches. It could be implemented through bilateral collaboration between two countries, through multinational research programs (such as those sponsored by IIASA, OECD, and CMEA, or through such United Nations agencies as the Office for Science and Technology [1,2] and the United Nations University.* A loose coalition and liaison among some or all of the above programs and agencies is probably the most desirable and feasible way to proceed.

The agenda suggested shows how international TAs could gain depth in a sequence of steps. It is not necessary that all of the 10 steps be taken before breadth is attempted. In fact, we suggest that a balanced approach be taken to increase both depth and breadth simultaneously, although gradually. A broad international TA program would include:

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*Other UN agencies with potential interests in international technology assessment include IBRD, ILO, UNDP, UNEP, UNESCO, UNIDO, and WHO.

- Cooperation in the field of information and administration of technological development (intergovernmental level, international agencies' level etc.);
- Joint international TA projects in substantive areas (e.g., arms control, space exploration, protection of the global environment, searching for new resources of energy and developing appropriate technologies);
- Joint R&D programs and projects concerning TA methodologies;
- Agreements limiting R&D, production, and distribution of harmful or dangerous technologies (e.g., in such fields as biology, medicine, and chemistry);
- Creation of an international or global early warning system for monitoring and predicting the possible negative effects of ST;
- Effective dissemination of substantive TA results for any government or other entities;
- Popularization of the TA concept and methods by various forms of education (e.g., international universities, summer schools, conferences, publications, and mass media).

Special attention should be given to the problem of TA within Third World countries, involving their nationals. Choice of a technological path for the developing countries is crucial and should not be limited only to technological and economic aspects. It would be desirable to compare and re-analyze the "intermediate" or "appropriate technology" concept [21,22], together with the concept of TA. The limits and opportunities of the late-comers' situations should be assessed, using multidimensional criteria (e.g., internal self-reliance possibilities and barriers, versus external aid possibilities and hazards). International (e.g., African, Asian, or South American) and world (United Nations) organizations responsible for scientific and technological assistance to the developing countries should assess the cultural and social impacts of this assistance in order to promote technological developments that would be genuinely suitable to their specific needs and conditions. Truly effective international TAs involving the Third World would lead to a reshaping of not only the economic world order [23], but also the scientific and technological world orders.

We believe that an in-depth cross-national understanding of TA premises and processes is a prerequisite for international TA, which will involve the nationals of two or more countries and provide serious inputs to the technology policymaking pertinent to some substantive problems shared by these countries. Appropriate and effective common methodologies can then be developed for international TAs involving these countries without a complete agreement on premises and processes. Eventually, new and effective methodologies and institutions for international TAs can emerge after sufficient learning from the actual experience through international collaborative efforts.

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A Strategy for Organized Technology

G. Dobrov

THE CONCEPT OF ORGANIZED TECHNOLOGY

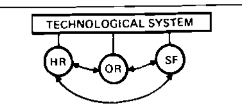
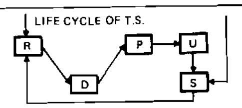
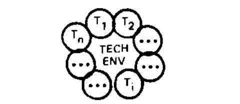
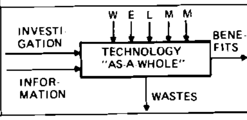
In recent years there has been increasing recognition that science has an important social mission as a potential and direct productive power, a mission that is realized through the creation and correct adaptation of new technological systems. Through the efforts of individuals, teams, and institutions devoted to technology creation and utilization, technological advance has faced a broad spectrum of national and international needs and has managed to overcome many constraints and satisfy many social demands.

However, the need for analytically based and future-oriented management of socially organized technology has also been increasingly recognized by both developed and developing countries. During the last 10 to 15 years, within the framework of science and technology (ST) policy studies and within the various branches of systems analysis, new types of research have developed called technology forecasting (TF), technology assessment (TA), alternative technologies (AT), evaluation of R&D (ERD), and science/technology-potential (STP) indicators. For this set of analytical efforts the general heading of Systems Assessment of New Technology (SANT) has been proposed [1]. The object of SANT is organized technology.

For different regions of the world and different levels of decisionmaking, there are different systems of technological strategies and priorities. But there is a universal demand, common to national and international needs, to develop an appropriate and effective system for the management of technologies that will help mankind to meet the vitally important challenges of the WELMM approach--the assessment of energy resources in terms of the impact of their development and harvesting on water, energy, land, materials, and manpower. At the moment it is thought that this challenge, and especially the new and future scarcity problem, may be so serious as to demand the involvement of a different type and combination of technology as well as perhaps the limitation of some activities [2]. The need for comprehensive technological management is thus all the more obvious.

Applied systems analysis has come to be understood as a set of efforts directed toward the managerial problems of the creation, transfer, and mastering of new technologies; efforts which are urgently needed for the WELMM approach, particularly the future process of mutual substitution of WELMM components, which may well be among the main factors affecting the further development of mankind. To put it another way, one of the highest strategic priorities is that the WELMM approach should be combined with the STM (science-technology-management) approach in the theory and practice of organized technology.

In the systems framework, organized technology has various meanings that complement each other; this should be taken into account when we consider the problems of policymaking and management in the field of ST. Four hierarchical levels or aspects of the systems interpretation of organized technology are shown in Figure 1. Later in this paper, attention will be given to each of these levels.

ASPECT	CONTENT	LOGICAL SCHEME	PATTERNS OF APPLIED SYSTEMS ANALYSIS	SANT
I SINGLE SYSTEM	A SYSTEM THAT CONSISTS OF TECHNICAL MEANS ("HARDWARE"), PRINCIPLES AND METHODS ("SOFTWARE" OR "KNOW-HOW"), AND SPECIAL ORGANIZATION ("ORGWARE")		TECHNOLOGY TRANSFER; APPROPRIATE TECHNOLOGY; TECHNOLOGICAL CHANGE;	TF, TA, AT
II PROCESS OF ACTIVITY	A PROCESS OF ORGANIZED ACTIVITY IN THE FRAMEWORK OF THE LIFE CYCLE OF A TECHNOLOGICAL SYSTEM: RESEARCH, DEVELOPMENT, PRODUCTION, UTILIZATION, SUBSTITUTION		MANAGEMENT OF INNOVATION; PLANNING AND PROGRAMMING OF TECHNOLOGICAL CHANGE; MANAGEMENT OF CONFIGURATION OF TECHNOLOGICAL SYSTEMS;	TF, TA, AT, ERD
III FAMILY OF TECHNOLOGIES	A MAN-MADE ENVIRONMENT AND MATERIALIZED KNOWLEDGE WHICH MODIFIES THE VOLUME AND STRUCTURE OF AVAILABLE RESOURCES AND MANKIND'S POSSIBILITIES		"QUALITY" OF TECHNOLOGICAL ENVIRONMENT; TECHNOLOGICAL SUBSTITUTION; MANAGEMENT OF TECHNOLOGY TRANSFER AND INNOVATION; TECHNOLOGY ADVANCE;	TF, TA, AT, ERO, STP
IV TECHNOLOGY-AS-A-WHOLE	A HOLISTIC OBJECT OF SOCIAL MANAGEMENT ON THE DIFFERENT LEVELS OF DECISIONMAKING		TECHNOLOGICAL PROGRESS; "NATIONAL" MACHINERY OF TECHNOLOGY TRANSFER AND ADOPTION; ALTERNATIVE TECHNOLOGIES; SCIENCE/TECHNOLOGICAL POTENTIAL;	TF, AT, AT, ERD, STP

*HR, hardware; OR, orgware; SF, software; R, research; D, development; U, utilization; S, substitution; P, production.

Figure 1. Main aspects of organized technology.

TRENDS NECESSITATING INTERNATIONAL ST POLICY

A new generation of ideas about ST policy and R&D management is needed in order to deal with some of the essential trends in present-day development of ST. For instance, the role of science and its technical applications in the solution of a very broad spectrum of the problems of contemporary society is rapidly growing. The social role of ST is shaped by the continual process of transforming practically applied scientific knowledge into direct productive power and social capabilities. This process brings about new possibilities and hopes, but it can also cause new problems and anxieties. The character and dynamic structure of these positive and negative consequences of technological applications are heavily influenced by the growing complexity of newly created technological systems, the diversity of their forms, and the intensification of their ties with other systems.

One important regularity in the course of technological change is the need for continuous growth of "science capacity". Each new generation of technology, of new kinds of products and production, requires more research and experimental development efforts. In fact, for a given amount of advance in production, even greater advances in ST are required.

The necessary strategical relation is:

$$\frac{dS}{Sdt} > \frac{dT}{Tdt} > \frac{dP}{Pdt} \quad ,$$

where S is science, T, technology, and P, production. In areas where this relation holds true, the pace of technological substitution is observed to grow (see Figure 2). It is obvious, of course, that for different countries, different problem areas, and especially different stages of development, this relation may vary and must therefore have an appropriate definition within the framework of ST policy (see Figure 3).

Another problem may also be indicated here. We must pay more attention to the long-lasting effects of ST solutions on a worldwide basis. This is a dimension of the important problem of appropriate technology, which is being much discussed at the moment [3]. The same can be stressed if we try to reformulate the recently coined idea of "small is beautiful" [4]. Our perception of what is small or big or how beneficial it is changes over the course of time, from country to country etc., but it is certain that lastingly effective and truly appropriate technological options are beautiful indeed.

The colossal amount of material and intellectual resources allotted to technological development is doubling in volume approximately every decade. As yet, however, in not a single

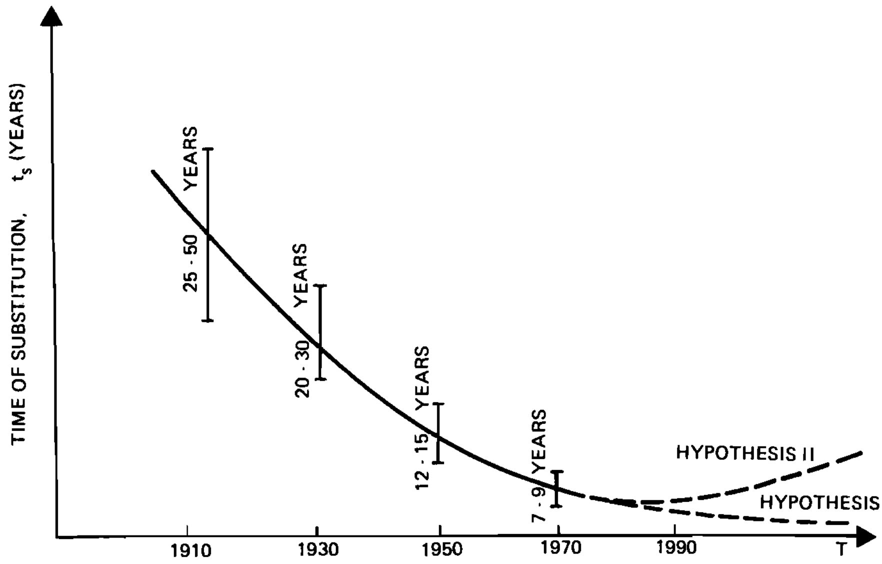


Figure 2. Trends and prospects in technology substitution time.

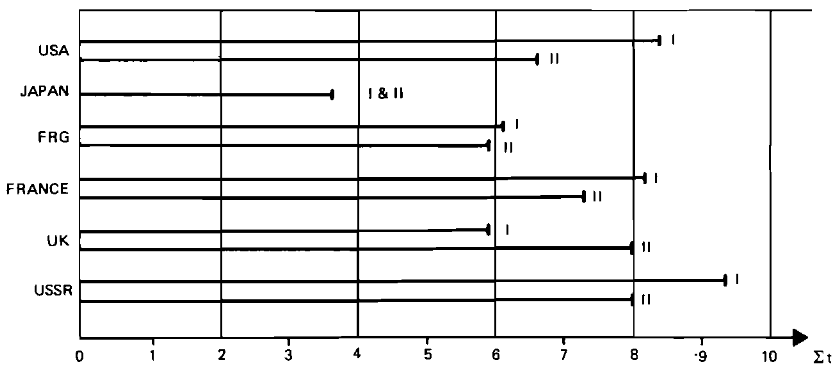
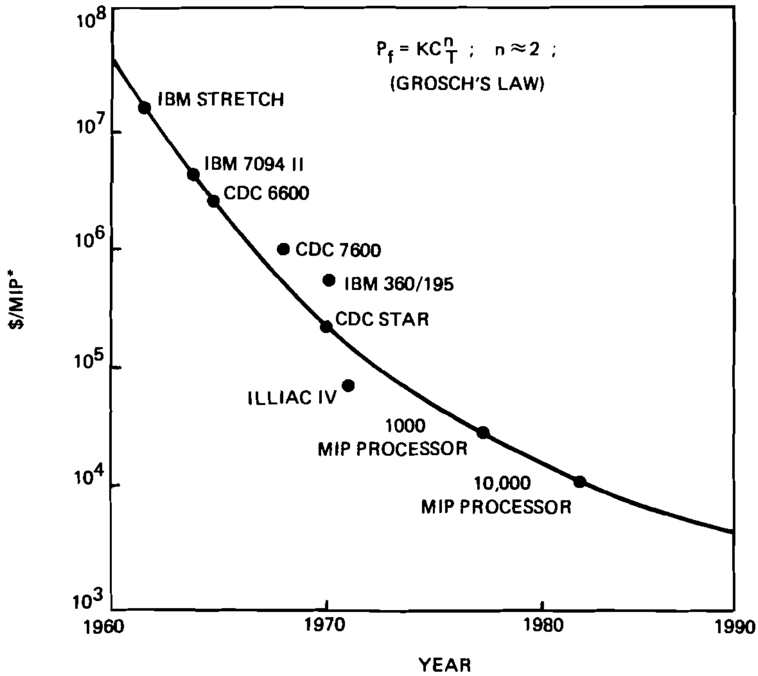


Figure 3. Time-lags in technological substitution, by country (approximate).

$\Sigma t = t_{R\&D} + t_{introd.}$
I, 1953 - 1963
II, 1963 - 1973

Source: [3], citing Gellman Research Associates. USSR data from the Institute of Cybernetics, Kiev, USSR.

country has this process been accompanied by a correspondingly rapid rate of growth in the efficiency with which these resources are used. Nevertheless, some essential shifts in the patterns of technological change are discernible. There is a distinct tendency towards the improvement in cost effectiveness of new technological systems defined in terms of the parameters of technological functioning (see Figure 4). In many cases this tendency can even reverse the still-existing rise in total cost of industrial technological systems. To describe this overall tendency, "Grosch's law" has been proposed--an observation that the functioning power of technology (P_f) increases approximately in proportion to the square of the cost (C) of the given technological systems. That is, $P_f = KC_T^n$; ($n \approx 2$, K is a constant). Analysis of data about the development of computer technology has showed a shift in the value of the co-efficient n from 2 to 2.5 and then to 3 [5]. In general, the cost situation in technological changes can be expected to be much more favorable in the future.



*MIP is a widely used measure of computer performance, representing the inverse of the weighted average execution time of a set of institutions typical for a particular class of computing tasks. Here, the instructions and their weights are fixed: add (0.7) and multiply (0.3).

Figure 4. Cost projections for high-performance general-application computers.

Source: [5]

Analysis of a macromodel that defines returns on research and development (R&D) expenditure (a function of the life cycle of technology) shows the important role not only of technological factors themselves but of organizational, managerial, and economic factors as well (see Equation(1)). In this connection, it is known that the fate of ST strategies is much more sensitive to mistakes in time estimation than in cost assessments (see the data in Table 1 and Figure 5) a fact that must be taken into account in any system for the management of organized technology.

$$\gamma = \frac{E_{(i)} t_{us} \bar{N}}{\bar{q}_{rd} t_{rd} K + \bar{q}_{int} t_{int} N^*} \quad \left[\frac{\text{units of output}}{\text{units of inputs}}\right] \quad ; \tag{1}$$

where:

$E_{(i)}$ is the effect of using i-th new technology system for one year;

t_{us}, the time for use of this technology before substitution;

$\bar{N}$, the average number of technological systems in operation during time t_{us};

$\bar{q}_{rd}$, the average cost of one year of R&D for preparation of this technology;

t_{rd}, the time of R&D needed for preparing this new technology;

K, a co-efficient of multiplication and proportion of unsuccessful R&D projects ($K \geq 1$)

($K = 1$, if we have a single successful project
$K = m$, if K is a multiplicative factor);

$\bar{q}_{int}$, the average cost of one year of the process of plant and market introduction of this new technology;

t_{int}, the time needed for introduction of one technological system; and

N^*, the number of introductions needed for transfer of this new technology.

Finally, two other crucial features of the present experience of ST development which should also be stressed are:

- The diminished role of a free market as an automatic regulator of the process of forming technological changes;

Table 1. Estimation of the structure of efforts in the life-cycle of technology.

Source: [6]

Stage			Cost (%)	Time (years)
INNOVATION		Goal Setting	1	?
INNOVATION		Research	5 - 10	2 - 3
INNOVATION		Development	10 - 20	1 - 2
INNOVATION	INTRODUCTION	Preparation for Production	40 - 60	1
INNOVATION	INTRODUCTION	Organization of Manufacture	5 - 15	1
INNOVATION	INTRODUCTION	Organization of Market	10 - 25	1
		TOTAL	100	6 - 8

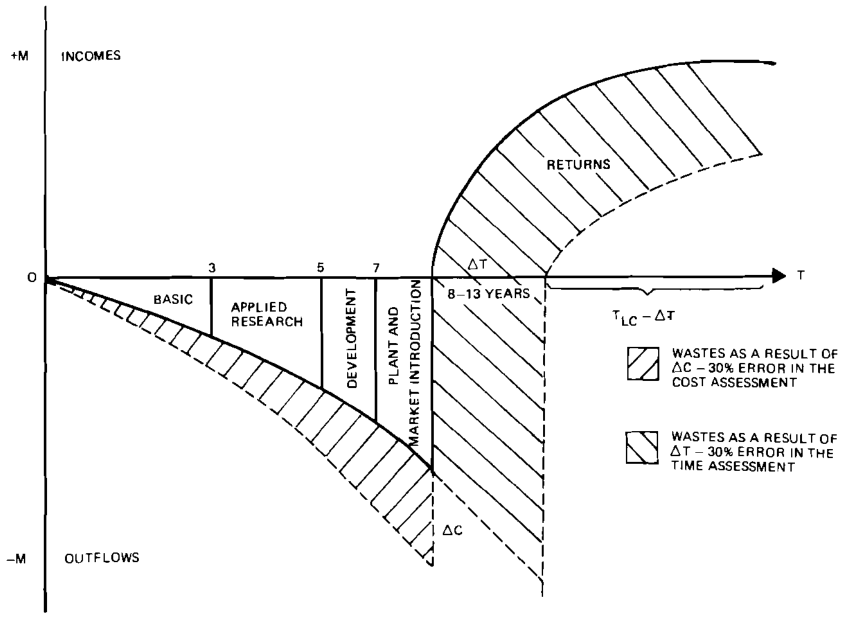


Figure 5. Comparison of losses (L) from errors in estimates of cost and time in R&D projects.

- The increased role of various forms of international cooperation and technological exchange in the process of national technological advance.

As regards the first feature, it is clear why all countries have a great interest in improving methods for state ST policy-making, forecasting, assessment, planning, programming, stimulation, etc. The main function of the analytical procedures that have been proposed for this is not only to justify management decisions but also to broaden the practical possibilities for the participation of people in the ST policy process.

The second feature is crucial and is well known as the demand for "equal and mutually beneficial" international ST cooperation (accepted in the main documents of the United Nations and in the Helsinki Declaration). One could add to this definition "worldwide and long-range effective cooperation".

THE IMPORTANCE OF ORGWARE

Turning now to the first of our four hierarchical levels of organized technology, namely the level of single systems, let us observe the fact that good hardware and software alone are not enough to assure an efficiently functioning system. Experience gained during the last decade has made it clear that, to achieve technological advance, as a rule it is not enough to have only a set of technical means or even skilled staff. These must be supplemented by special organizational (in more general terms, socioeconomic) innovations. To prove the point we can recall lessons learned in connection with many scientific and technological shocks or national and international difficulties in technology transfer.

To achieve success, each modern technological system urgently needs a specially designed organization to provide for the utilization of decisionmakers' skills and the interaction of this system with other systems of different natures. We refer to this as "orgware".

On the macro-level, orgware encompasses a set of special economic and legal regulations (a system of prices, taxes, stimuli, and constraints). On the operative level, orgware includes organizational-structural solutions, procedures for management, training of manpower, maintenance service, and special ways of interacting with other systems (see Figures 6 and 7). As a general rule, the more potentially effective a new technology is, the more urgent the need for specially designed orgware will be.

An organizational framework for technological progress must be designed with the help of reliable special analytical methods, just as hardware and software are designed with the help of their appropriate methods.

TECHNOLOGICAL SYSTEM				
BASIC SYSTEM COMPONENTS	HARDWARE	ORGWARE		SOFTWARE
EXAMPLES OF STRUCTURAL ELEMENTS	OPERATIONAL MACHINES AND APPARATUS	ORGANIZATION OF THE SYSTEM AND OF ITS MANAGEMENT		OPERATING PRINCIPLES
		ENGINEERING ASPECTS OF OPERATIONAL PROCESSES	METHODS OF LEADERSHIP AND MOTIVATION, ADMINISTRATIVE, AND LEGAL REGULATORS	PROCESS INSTRUCTIONS AND RULES
	MEASURING INSTRUMENTS	SUPPORT AND TECHNICAL SERVICE	PRICES, TAXES, ECONOMIC NORMS AND STIMULI	WORKING INSTRUCTIONS
	COMPUTATIONAL AND CONTROL EQUIPMENT	NETWORK OF COMMUNICATION AND INTERACTION	PROFESSIONAL TRAINING	PROGRAMS AND MATHEMATICAL ROUTINES
	RECEIVING AND SHIPPING EQUIPMENT	PERSONNEL SERVICES AND ORGANIZATION OF LABOR		METHODS AND DESCRIPTIONS
	⋮	⋮		⋮
	ASSEMBLY AND WAREHOUSING OF COMPONENTS AND PARTS	ORGANIZATION OF SUPPLY	ORGANIZATION OF COMMUNICATION AND SYSTEM MEMORY	CATALOGS AND OTHER SYSTEM DOCUMENTATION

Figure 6. Structure of systems technology.

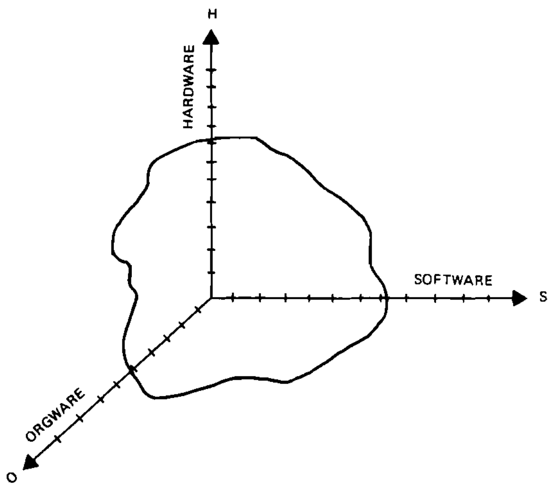


Figure 7. The dimensions of systems technology.

The organizational framework for technological progress is one of the main problems of future technological change. In many regions of the world, a number of very acute problems which must be solved demand that a policy design for new technologies be reconsidered from the systems viewpoint. Some crucial problems for various parts of the world may be mentioned:

- Accelerated growth of labor productivity and diminution of unemployment as a result of the wide use of new and appropriate technology;

- Solving complex food and agriculture problems on the basis of systems realization of new technologies;

- The "blue revolution" in environment and nature, expected in view of forthcoming technological opportunities;

- Creation of a "zero-waste" technology for the whole chain of productive processes, from discovering resources to the goods for consumption.

The experience gained, both through IIASA investigations and our previous scientific activities, strongly supports the concept that, in cases where organizational and managerial aspects of systems technologies do not get proper consideration, the effect expected by society for solving key problems is seldom achieved, despite considerable investment made in the other two components of technology (hardware and software).

The specific organization (orgware) should be designed as both problem oriented and machine oriented. There are also some whole-system criteria such as: minimization of time delays and optimal storage and use of information. Inter-systems criteria define the ability of a given system "to be appropriate to the conditions of application". They must play a particularly important role in designing orgware as well as hardware and software.

The development of models and methods for designing the orgware as a systems element of new technologies is one of the most acute problems for systems analysis of organized technology in the near future.

LIFE CYCLES OF TECHNOLOGY

The strategy of organized technology must also be discussed on the second of our four hierarchical levels, namely that of operational management of the life cycles of specific technological systems.

The practice of managing technological change has revealed several important trends:

- The rate of substitution of technology generations is increasing; during the twentieth century the time period for such change has been halved about every twenty years.

- The time and cost of the R&D parts of the technology life cycle are becoming larger; during the last five to seven years, the statistically estimated length of projects has increased by 1.3 to 1.5 times and their cost more than twice.

- The time spent on decisionmaking in organizational management is tending towards growth. Known data, as well as personal observations, show that the total time of waiting for managerial decisions can exceed the general duration of all other actions in the life cycle.

An active patent and licence policy, international cooperation, and technology exchange are important for all countries, but especially developed ones, as an effective option for the above-mentioned constraints. There are data that show that if all available ST information were utilized, it would be tantamount to at least a doubling of efforts in research, development, and technological innovation.

Technologically developed countries have also useful experience in solving problems in other ways. Some examples are MBO (management by objectives), PPBS (planning, programming, budgeting systems), selection of portfolio R&D ideas, and technological program risk evaluation. The USSR has experience in long-range and operational planning of R&D, goal-oriented programs of technological advance, and improvement of managerial efficiency by applying a set of systems demands such as "speed up", "wide spread", and "complete" utilization of available R&D results in the life-cycle of technology. The generalization and exchange of such experience is a promising field for international cooperation.

STUDYING THE FUTURE OF TECHNOLOGICAL ENVIRONMENTS

In discussing our third level of organized technology, namely "families of technologies", we should note that the concept of organized technology is, to a considerable extent, similar to the systems approach adopted in ecology. Water, land, air, etc. are studied by specific sciences. Each of these sciences has its own language, indicators, and models, which very often happen to be incompatible with those of other sciences. The value of social consideration of these elements within the framework of the theory of ecological systems and practical environmental monitoring has therefore been widely recognized.

Various families of technologies that have been created and are being used, as well as those that are being mastered at present, form a new kind of unity. This unity specifically interacts with nature and society. An applied systems analysis approach to a man-made technological environment is the only way to elaborate and put into operation such concepts of practical importance as a rate of technological substitution, quality of technological environment, technological risk, and flexibility of a technological system. It implies the capacity of the technological environment to accept new scientific and technological opportunities and to respond to changes of social, economic, and ecological demands, etc., including those that will develop in the future.

There is a common understanding that an analytical method of policy design is an important final step in modern systems analysis. For many kinds of activity (among them industry, agriculture, public health service, and administration) such policy-design efforts inevitably involve consideration of the state of relations among the activity in question, technology, and the economy.

In fact, many specific subjects to which systems analysis is applied, such as natural resources, environment, energy complexes, agricultural production, human settlements, and health care systems, can be reasonably explained only when long-range scientific and technological factors and socioeconomic criteria related to these factors are taken into account.

In Figure 8 we have arranged technologies of a given family along the T (technology) axis, beginning with widely known and practically used ones and ending with hypothetical or theoretically possible ones. The S axis represents a number of different real-world situations that affect the feasibility (economic and other) of the various technologies. Together, these two axes produce a map of theoretically possible conditions, each point on the map corresponding to the prevalence of a given technology under a certain set of conditions. Thus, a path across the map denotes change across time in both circumstances and prevalent technology; that is, a hypothetical trajectory or scenario of sociotechnological change. In Figure 8, several such trajectories are indicated as single zig-zag lines, although in fact each trajectory should be thought of as a broad, fuzzy line to account for both the possibility of several technologies and/or several sets of conditions coexisting at one time and for uncertainty.

As the illustrated trajectories show, the location within the stated space that corresponds to reality can change rather rapidly. Success in the R&D field can expand the set of technologies that are available from the viewpoint of ST. On the other hand, the society may become richer or may be influenced by some acute needs and thus change its economic criteria, or improvement in existing technologies can lead to better cost benefit indices. Modern techniques of systems analysis applied

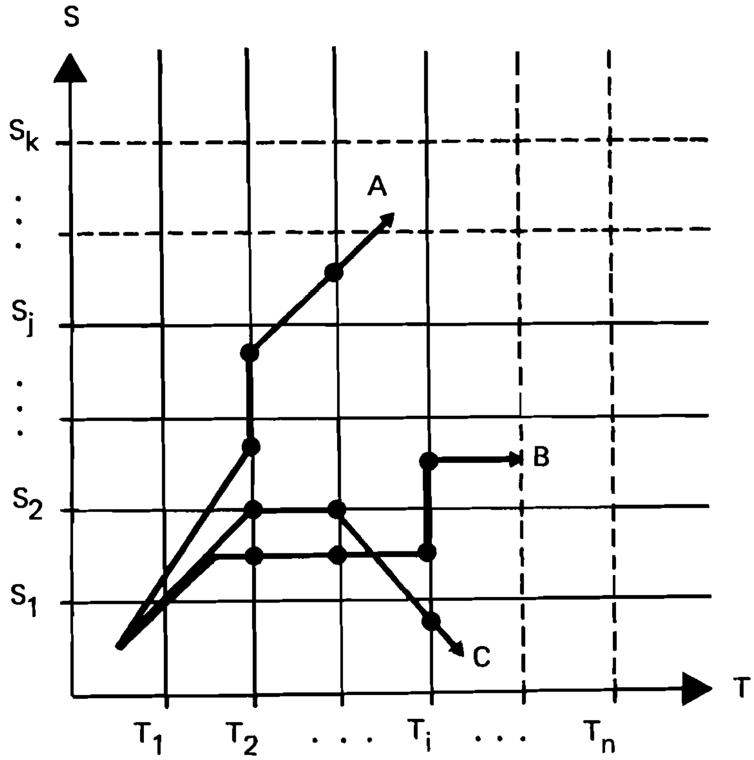
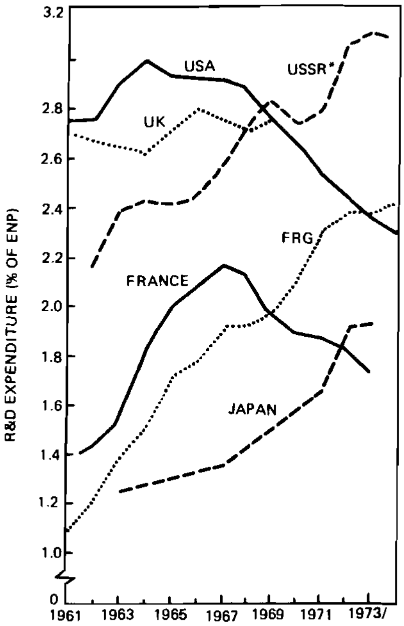


Figure 8. The space of technologically caused states for policy design.

in the field of technology (technological forecasting, TA, choice of technological alternatives, and the like) not only permit analysis of such tendencies in terms of quality and structure but also allow definite quantitative estimation of future states in the space. Here models of technological substitution and methods of cross-impact analysis have been successfully applied during recent years. For decisionmakers, it is quite evident (see Figure 9) that trajectories A, B, and C differ considerably in their implications for policy design.



*USSR estimates by R.W. Campbell, Indiana University.

Figure 9. R&D expenditure as percentage of gross national product (GNP), by country, 1961-1974.

Source: [2]

THE OPTIONS FOR TECHNOLOGY AS A WHOLE

At last we come to the fourth level of organized technology that of technology as a whole. The systems concept of organized technology assumes that technology should be studied as a unique object of management, an object that influences the activities and behavior of individuals, collectives, and organizations, while using knowledge, investment, and available natural resources. However, between the levels of technological achievement on the one hand and the final economic indices on the other, only implicit connections exist through complicated social and economic mechanisms. The attempt to study this phenomenon appears encouraging only by means of macromodels that take into account the essential time-lag between input and output.

In a model of this kind developed at the Institute of Cybernetics, Kiev (see [1, pp. 50-56]), the following set of variables was used: the rate of growth of national income, the estimated economic growth of ST potential (i.e., the growth of expenditures on R&D--see Figure 9), the delay (in years) between inputs to and outputs from the system, and the time-horizon of projected decisions. For example, two variants of possible policies are given in Table 2.

Table 2. Two possible policy variants.

	Time Horizon	National Income Growth	Time-delay T (years)	Final Annual Level of Investment in STP (Rubles)
Scenario I	1960-1990	× 7	9	76×10^9
Scenario II	1960-1990	× 7	7	48×10^9

The concept of STP is of special importance when systems technology as-a-whole is considered. The concept of technological potential (TP) being complementary to the well known concept of scientific potential, they together form a systems concept of scientific and technological potential, which is of special importance for analyzing problems of international cooperation in the field of ST and for preparing mutually beneficial plans and programs of scientific and technological exchange and transfer of technologies as well as for global, national, or industrial technological policy design.

TP is defined as the capability of a certain state or region of the world for the creation and application of new technologies which meet the challenges of further social and economic development. Experience gained at the Institute of Cybernetics, Kiev, and many studies carried out by the United Nations Educational, Scientific and Cultural Organization (UNESCO), the Council for Mutual Economic Assistance (CMEA), and the Organisation for Economic Co-operation and Development (OECD), and other international institutions, as well as recent studies of the problems concerning information technology, have made it possible to define the indices of TP for various countries and for different time periods.

Current states of variables of TP for a given country or world region are calculated in terms of fractions of corresponding values of the base year 1990. The results gained permit analysis of the dynamics, perspectives, and needs of countries and regions of the world in expanding and enhancing international scientific and technological cooperation and the mutually beneficial exchange of new technologies.

The regions to be studied could be selected by following the Club of Rome tradition or by the scope of influence of United Nations agencies and programs. It might be interesting to estimate to what extent the various regions are technologically ready to meet the "green revolution", the "blue revolution", and other crucial changes in ST.

TOWARD THE SANT

In recent years, in the USSR, the USA, and other countries, special investigations have been conducted regularly and on an ever-greater scale, oriented toward the analysis and comprehensive evaluation of the state of the art in various technological areas, toward the forecasting of their development, and toward estimation of their possible influence on the economy, on resources, on the environment, on other technical systems, and on society itself. Such systems investigations, undertaken on behalf of agencies that formulate and execute ST policy, have urgently required state organization of research as well as professional participation by systems analysts. Applied systems analysis of this kind is known in world practice under various names such as technology assessment (TA) and technology forecasting (TF).

In the USA, for instance, the National Science Foundation has included under the rubric of Exploratory Research and Systems Analysis practically all elements in the logical chain of decisionmaking [7]. These elements are: to forecast, to assess, to choose alternatives, to evaluate R&D efforts, and to allocate resources according to the potential possibilities to achieve technological results. Moreover, an expert invited by IBM noted that "there is considerable business support for such single-discipline studies as economic and technological forecasting. The time is now ripe to add a comparable level of effort in social forecasting and to integrate the three..." [8].

Another example is the OECD concept of social assessment of technology (SAT). This concept

> ...is defined as a process of analysis, forecasting and assessment of technological futures and their impacts on society resulting in action options for the decisionmakers. On the analyst's side, it encompasses the study of technological parameters, the elaboration of technological forecasts, the analysis of social, environmental, cultural and political factors, the general assessment of all relevant effects and possible consequences of a technology and an evaluation of alternatives.

In our investigations in the USSR, the general rubric encompassing all these concepts is SANT. According to recent estimations there are more than one hundred methods, models, and procedures for SANT. Some of these methods have already shown their usefulness relative to all of the elements of SANT. Others, however, have so far been tried only in particular cases.

Our general assessment of all known methods is this: that there is not and cannot be one universally good (and unified) method; but that there is also no basis for saying that any method is hopelessly bad for all cases. The problem is to find systematic means of using a selection of methods that compensate for each other's weaknesses. This is the same as the problem of creating a reliable system from relatively unreliable parts. We know of at least one example of the successful solution of this problem (*Homo sapiens*).

Recently the attention of the senior advisors of the Economic Commission for Europe (ECE) governments on ST was drawn to the methodological experience of multinational ST forecasting in CMEA member countries. The methodology used in this activity is derived from [9], which was approved in 1971 by the collegium of the State Committee on Science and Technology of the USSR as the basic methodological instrument for SANT. Since 1975, the CMEA countries have had a joint methodology for multinational work in technological forecasting created on the basis of [9], but utilizing the CMEA countries' experience with forecasting. (For further details on this subject, see Glushkov et al. in this volume.)

With the use of these methodologies, and in various technological areas, assessments are now being obtained that are practically related to all of the elements of SANT: prognostic technological data, estimates of the possible influence of technical achievements, comparison of variants of technological policy, comparison and evaluation of R&D projects at the stage of their inclusion in plans and programs, and advance estimation of the ST potential that could be drawn in for performance of expedient efforts.

The foregoing illustrates the possibilities that exist for international cooperation in the field of applied systems analysis of organized technology.

CONCLUSION

ST have certain inherent qualities that are basically international. However, international cooperation in setting science/technology policy represents a very recent form of activity. Its importance is growing rapidly for all countries, without exception and in some ways, for the fate of the world as a whole. Nevertheless, the theoretical and methodological elements (concepts, indicators, models, and decisionmaking procedures) needed for this activity are, if not entirely absent, often drawn from such inappropriate fields as international trade.

To improve the tools of national and international ST policymaking would be a valuable step toward the realization of one of mankind's strategy hopes, namely, mutually advantageous and effective worldwide scientific and technological cooperation, with equal benefits for the development of all countries involved.

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Social Assessment of Technology and Some of Its International Aspects

F. Hetman

At least in technologically advanced countries technology has been the major factor in liberating man from his basic ancestral fears: hunger, illness, and insecurity. This seems to explain why technology has won support from all sides. It has come to be considered as a kind of bounty, transcending individuals and societies as an autonomous force.

However, such a fatalistic fostering of technology and of its unconditional diffusion has led to new threats to human existence, such as nuclear destruction, ecological disaster, depletion of natural resources, and malnutrition owing to the failure to curb the population explosion. At the same time, technical change makes obsolete whole categories of knowledge, productive processes, professional skills and occupational patterns. All of this gives rise to economic and social disruptions and feelings of frustration on both the social and individual level.

Thus, as a consequence of the very success of scientific research and technological change, mankind is now faced with new risks and dangers. These are manmade; there are no natural or supranatural correcting mechanisms that can be applied. From now on, men will have to come to new terms with technology-induced human systems and devise new ways of bringing technological innovation and proliferation of techniques under some kind of social control.

This necessity runs counter to a largely accepted and almost unquestioned conviction that technology is a basic factor of social change that acts upon society in an irresistible and self-enhancing way. Such a conviction is commonly held by the followers of most prevailing political doctrines and is based on several currently admitted views.

A CHALLENGE TO TECHNOLOGICAL DETERMINATION

An often repeated contention is that technological innovation is, by definition, a self-contained process. By its inner logic, namely, the pursuit of an improvement in a specific performance or an increase in productivity, each separate technology creates opportunities for constant innovation. In a sense, innovators are merely the revealers of new and gradual steps forward in a basic trend along a given functional trajectory. Furthermore, technological innovators are stimulated by scientific discoveries that become available through research and development, while scientific research in turn is stimulated by the firmly held belief in scientific freedom.

Dialectically, this technological determinism is frequently opposed to the apparent capriciousness and instability of social phenomena. Such an opposition is interpreted as the progressive inability of man and society to adapt to the pace set by technological development. According to this interpretation, while technology is advancing at an accelerating pace, human adaptability and social structures in general are stagnating if not actually regressing. This discrepancy ends by provoking a feeling of frustration that contributes to accentuating the lack of confidence in existing social institutions and to the prevalence of a gloomy view of increasing alienation.

Whatever the grounds on which this way of thinking is based, it reinforces the thesis of technological determinism in that it accepts as evidence that human, social, and ethical phenomena lag behind technological developments. It implies that social problems tend to derive from technological change. Impacts are generated by technology and move in a linear fashion from technology to society. Society merely reacts, through feedback loops, in a rather haphazard and incongruous manner.

Arguments like these reveal a basic misinterpretation of the essence and societal role of technology. A comparison between the rates of technological advance and the evolution of society is quite irrelevant. Technology is but one of the possible methods for coping with various social problems. A given technological development can provide an improved means, but it cannot determine the rationale and content of a social achievement.

A NEW ATTITUDE TOWARDS TECHNOLOGICAL CHANGE

The new threats and problems created by technology make it more and more obvious that technological change does not automatically and necessarily mean technological progress, real economic growth, and, still less, an actual increase in social welfare and human satisfaction. Conventional criteria of economic growth appear to be of limited significance; the so-called indicators of "progress" are increasingly contested.

Consequently, new tools for decisionmaking in the field of technology are needed. Since it has been recognized that technology can be the source of both benefits and undesirable effects, a drastic change in thinking and general attitude towards technological change is now taking place.

This change calls for a new course of policy for which neither governments nor individuals have been prepared. Governments continue to favor technological innovation as a means of attaining and maintaining full employment of available resources and sustained economic growth. At the same time, they are solicited to take strong action to reduce the negative effects of technology and, above all, to define new policies likely to make it possible to direct technology towards socially desirable ends.

How can such broad and diffuse fundamental but also partly contradictory goals be pursued? As an answer to this question a new aid to decisionmaking has been suggested: technology assessment (TA) or rather social assessment of technology (SAT).

The term was coined about ten years ago by the Science, Research and Development Sub-Committee of the House Committee on Science and Technology of the United States Congress. It was then defined as a form of policy research, a method of analysis that systematically appraises the nature, significance, status, and merit of technological progress with a view to identifying policy issues, assessing the impact of alternative courses of action, and presenting findings.

As the notion spread, various activities and conceptual constructs have been subsumed under the same label. However, a review of the experience gained suggests that there are two main tendencies, diverging in approach and basic philosophy.

The first can be called the technologist's approach. It considers that TA examines the impacts of all possible policies but does not come out with specific recommendations involving value systems. Assessment ends at the frontiers of the broadened technological analysis, leaving the rest to the traditional, existing, social and political processes.

The second tendency, on the contrary, regards the management of technology as a part of overall planning or social engineering. In its extreme formulation, it starts by spelling out values, social policies, and objectives and works down to TA in order to clarify the most appropriate technical options.

These two points of view may be considered as extreme lines of definitional mapping between which SAT can take a great variety of forms. They are not mutually exclusive but rather complementary, as they address themselves to the same cluster of problems, but from different angles and at different levels of the decisionmaking process. At the present stage, both of them challenge scientists and engineers to develop better understanding of the interrelationships between technology and society. They also challenge decisionmakers, from individual organizations to central government, to evolve new procedures and institutional forms that can help them to build up a firmer basis for their technology policies.

Such procedures and mechanisms should serve to indicate new directions for technology and for scientific research. They will also have to make clear the possible detrimental effects at an early enough stage for remedial measures to be considered by policymakers. However, the difficulty is to ensure that policies and instruments are not so rigid as to hamper technological change and inhibit genuine social progress.

Theoretically, six main areas can be identified as starting points for TA studies: technology, economy, society, the individual, the environment, and value systems. However, for some of these and particularly for society, environment, the individual, and value systems, there is as yet little knowledge available on relationships with technology. Most frequently, therefore, TA studies are merely divided into two broad categories: technology initiated, and problem initiated. In a broad sense, from the technologist's point of view, the great majority of assessments are technology initiated, whereas from the social engineer's standpoint, most assessments should be considered as problem oriented.

Available examples of TA studies are mostly of the technology-initiated type. This can easily be explained by the fact that the first generation of assessment took place in direct response to questions concerning the particular environmental impacts of selected technologies.

A NEW AID TO DECISIONMAKING

The concept of SAT leads to a reappraisal of the role of science and technology (ST) in contemporary society, both with deeper understanding of the nature of technology and of the innovation process, as well as consideration of the consequences of alternative technological decisions and a new approach to better-informed decisionmaking.

Social assessment of technology can be defined as a process of analysis, forecasting, and assessment of technological futures and their impacts on society resulting in action options for the decisionmakers. On the analyst's side, it encompasses the study of technological parameters, the elaboration of technological forecasts, the analysis of social, environmental, cultural and political factors, the general assessment of all relevant effects and possible consequences of a technology, and an evaluation of alternatives.

On the decisionmaker's side, it implies appropriate institutional mechanisms which make it possible to: identify demands for technological change, gear scientific and technological knowledge to societal needs, make the best choice among socially desirable and politically feasible technological variants, determine suitable means of action, and plan the appropriate phases of implementation.

There is a close and permanent interplay between assessment study and decisionmaking. It takes the form of convergent iterations that are necessary to evaluate the consequences of technological change on society and to determine the channels through which the societal objectives can exercise their influence on the future course of technological development.

This interplay can be represented as a threefold systemic approach that integrates the processes of analysis, of decisionmaking and of information into one dynamic continuum, as illustrated in Figure 1. The analysis process itself is a multi-iterative feedback process that combines forecasting and evaluation methods to explore relevant societal aspects of a given technological development and to evaluate their impacts and consequences.

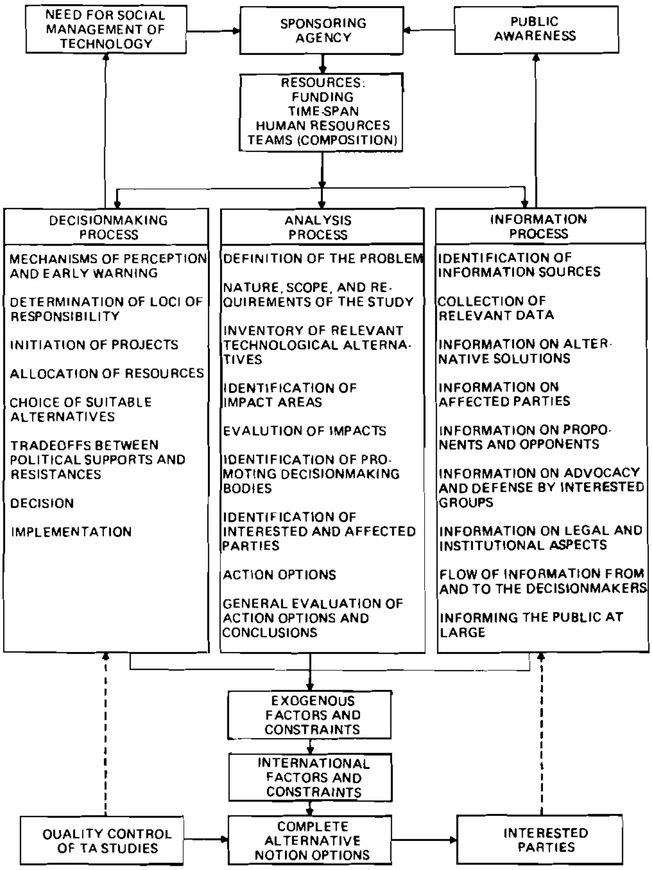

Figure 1. Process of SAT.

Source: [1]

INSTITUTIONAL STATUS OF SAT

Ideally, SAT should examine closely all potentialities of a technology. This implies that analysts are able to consider and evaluate all possibilities as to both their beneficial and adverse effects. However, any new technological development entails an infinite number of unpremediated consequences. There is no scientist or technologist who can take into account all of these consequences, which go far beyond the capability of any group of people to understand and to draw the social path of a given technological event.

These are important and sobering limitations. It is obvious that SAT is not a technical device but rather a change in attitude towards technology and a new approach to better-informed decisionmaking in this field. It is not concerned with technical expertise per se but mainly with sociopolitical answers to the impacts of technology. If the analysts are to provide useful information, their involvement, assumptions, sources of data, and methods of reporting to decisionmakers must be made clear so as to set workable boundaries to their effort.

What can the institutional status of SAT be? Is it an outgrowth of ST policy? Is it a new branch of general policy stemming from the reaction to the disenchantment with ST and the subsequent questioning of the ends of scientific activity and passive acceptance of technological developments?

One would expect that its status would be closely linked to technology policy. However, this has not been the case thus far; from the institutional point of view, technology has no place of its own. Both in national governmental agencies and relevant committees of the international organizations, the word "technology" was only recently added to the word "science". Although this addition marks an increased concern for questions of technology, the pair, science and technology, remains ill matched. While government agencies for science policy are now established with rather well-defined attributions, this is not the case for technology. In-depth investigations are still needed to identify the mechanisms of technological advance and of the interplay between technology and society before technology policy can be outlined in relevant operational terms.

OECD PROGRAM ON SAT

Organisation for Economic Co-operation and Development (OECD) work in the area of SAT was initiated in compliance with the new orientations for science policy, outlined by the Ministers of Science in their 1971 meeting. Exploratory research began with the organization, in January 1972, of the first international seminar on TA in which about 40 distinguished scholars, technologists and politicians participated. This seminar was devoted to discussions of possible approaches and usable methods, as well as of the first experiences in the field.

This exchange of information was a starting point for an in-depth exploration of the state of the art which led to the publication of *Society and the Assessment of Technology*, a comprehensive OECD report, examining the general philosophy of SAT, conceptual starting points and methodological frameworks, reviewing the available experience, establishing a general typology of assessment studies, exposing the methods of cost/benefit analysis, outlining the possible areas for use of assessment studies, examining the institutional problems and relationships between analysts and decisionmakers [2].

Another initiative was the establishment of an Advisory Group on Control and Management of Technology. This group was composed of high officials from a number of OECD member countries. Its main role was to inform the OECD Secretariat on national policy developments related to technology and its impacts on society. The discussions of this group were of great help in clarifying the needs in the area of SAT and in formulating the OECD program in it.

Both the theoretical work accomplished and identification of national views pointed towards the desirability of stimulating national studies and furthering international cooperation. The need was perceived to elucidate methodological issues and to set up guidelines that might be used by the member countries and the international community at large.

This work was undertaken with the help of a panel of experts and it led to the publication of *Methodological Guidelines for Social Assessment of Technology* [1] which outlines a general framework for social assessment studies. It is an attempt to reconcile the need for a comprehensive set of guidelines with the legitimate concern for practical usefulness. Obviously, such a framework implies a number of caveats and raises questions as to its adaptability to any specific subject. These points and other comments by the experts are included in the volume.

At the same time an activity was started that was intended to test the social assessment approach in applying it to real problems of the interested member countries. From a great number of topics suggested by national authorities, three subjects were selected for studies to be launched within the OECD program. These were:

- New Urban Transportation Systems--efficient modes of collective rapid transportation;

- Humanized Working Conditions--new modes of organizing work and working conditions;

- Telecommunications Technologies--instruments of regional planning and balanced regional economic and social development.

From the outset, two possible approaches were suggested by the OECD Secretariat: studies in cooperation by pooling available national resources in a common effort and studies in coordination, leaving each country free to organize the work at the national level. This second approach was preferred by the interested member countries. Consequently, the studies were to be carried out in parallel by national research teams, the OECD Secretariat assuring mainly the exchange and coordination of information.

The final objective was to make a comparative study of the national contributions with a view to identifying the main aspects where further improvements would appear desirable in future TA activities.

EXPERIENCE OF THE PROJECT "NEW URBAN TRANSPORTATION SYSTEMS"

Finally, a sufficient commitment could be secured for the first subject only: New Urban Transportation Systems. This project has been nearly completed. National reports from six participating countries were assembled, and the comparative synthesis is under preparation.

The project was carried out within the time span of about two years, following the first exploratory stage, devoted mainly to defining the practicability and operational steps of the methodological approach and to the identification of national studies that could be retained within the framework of the project.

To facilitate this identification, the OECD Secretariat prepared an outline of the general procedure along the lines of [1]. At the same time, two discussion papers were distributed that had been prepared by external experts. One was technology oriented and reviewed the main features and technical characteristics of new families of urban transportation systems. The second was methodology oriented and dealt with conceptual considerations likely to emerge in the process of application of SAT to problems of urban transportation systems.

The succeeding meetings of the national project leaders made it clear that none of the national organizations involved were ready or had the possibility to devote a sufficient part of its resources to a specifically designed social assessment study. Instead, proposals were made to derive some kind of contribution from the current work. In order to obtain at least some degree of similarity with respect to the format, a list of 12 common points was drawn up for guidance, with the hope that all participating research teams would be able to contribute to these items, and if not, to bring out explicitly the difficulties of assessment.

As a result, even if compared with an extremely limited common frame of reference, the national contributions received could hardly be considered as full-fledged social assessment studies of technology; they were usually parts of broader projects undertaken within the current programs and responsibilities of the respective research organizations. Frequently, they were merely derived from an already-completed work that had been carried out with a quite different objective in mind. Each of them was thus devoted to a particular aspect or point of interest so that it was particularly difficult to identify common areas on which a meaningful comparison could bear.

In general, however, a certain effort was made to introduce the idea of SAT either as an additional category of conceptualization or, more wholeheartedly, as a promising methodological tool, allowing for the exploration of aspects often neglected in traditional technical feasibility studies.

The attention of the participating research teams was progressively focussed on two elements of SAT, considered as a particularly useful broadening of the analysis, i.e., the establishment of societal scenarios and the involvement of concerned groups. This broadening explains why, among the six national contributions, two were devoted mainly to designing and evaluating scenarios or future states of society with respect to a given type of transportation technology; two other contributions reported almost exclusively on experiences gained with simulated implementation of the public involvement in the case of the introduction of a specific mode of transportation.

This is not a negligible result if one considers that the main thrust of the OECD program must have been to draw attention to the ideas and methodology of SAT with a view to making both the researchers and decisionmakers aware of its potential value to policymaking.

THE MAIN DIFFICULTIES OF INTERNATIONAL COOPERATION IN SAT

International cooperation is a means to an end. This statement sounds trivial, but it becomes serious when considering the definitions of ends that reach beyond national frontiers. National governments measure their participation in the light of their own needs, opportunities, and aspirations. They tend to consider international cooperation as a sophisticated barter conducted so as to yield positive tradeoffs and to enhance the nation's interests.

The Weight of Political Factors

It is widely accepted that technology has been a major force in fostering the interpenetration of policies and cultures and in creating the present state of interdependence, which seems to commend a coordinated view of world problems. In this perspective, is not one of the lofty goals of international cooperation, that of directing innovative energies towards ensuring that technology can increasingly contribute to improving the living standards and the quality of life in both developed and developing countries?

Nevertheless, technology is far from aiming at the same kind of universality as science. The weight of political factors increases rapidly as one moves from cooperative enterprises in science to those in experimental development and technology.

The Setbacks of Joint Undertakings

Since technology is now closely linked to organized research and development (R&D) on the one side and to a methodical launching of new product lines on the other, it plays a decisive role in economic efficiency and is therefore considered as the main source of competitive power. As such, it is surrounded by walls of secrecy during the phase of development and by patents and licences when ready for the market.

There are still other difficulties when it comes to joint undertakings on the intergovernmental level, as is shown by the experience of institutionalized organizations, particularly in Europe. Aside from intrinsic uncertainties as to the aims of cooperation, the most crucial problem is the unpredictable interpretation and defense of national interests. Joint undertakings may be called into question at any time as the result of a change in policy on the part of one of the participating countries. Moreover, international action adds to its own specific obstacles or restraints. What would pass at the national level for an effort of management or foresight will tend to be considered at the international level as a consequence of divergent views among the partners as to aims, results, or sharing of costs and benefits.

The Lack of Appropriate Institutions

As a new concept and a new approach to technological change and social policy in general, SAT must still find its place within the institutional set-up and decisionmaking mechanisms.

With the exception of the USA and its Office of Technology Assessment, there are no special institutions for SAT. In the present situation, it is extremely difficult to find, for any candidate for SAT, an appropriate institution that would be willing, able, and authorized to undertake such assessment studies. There is a wide dispersion of competences among the various ministries and agencies. Furthermore, institutions that show an interest in SAT--and there are often several of them, each responsible for but one aspect of a given technology--are hampered by their narrowly defined responsibilities. They have the greatest difficulty in modifying their programs in order to devote some resources to SAT.

In addition to these well-known phenomena of structural rigidity and institutional inertia, there is the fact that the concept of SAT is still badly understood and little propagated. For all these reasons, its usefulness is minimized and its implementation resisted.

The "Strait Gate" for Decisionmakers

It is often asserted that SAT must develop and organize the capacity and willingness of decisionmakers to perceive the full range of social consequences of technological developments. However, the results and warnings of SAT will be valueless if they are not accompanied by an adequate framework for response and action. This need raises several difficult points. Decisions must be made between competing and conflicting interests and values. Internalization of other than direct technical and economic effects implies a deep change in social and legal structures. This change generates, in its turn, its own externalities of psychological, sociological, and political nature.

As a rule, technology is developed as a trial-and-error process with opportunities for feedback from social, economic, and legal institutions. Such a feedback should allow technologists to modify and reshape a technology and to adapt it better to social objectives. In reality, there is little adaptation because the social consequences are difficult to clarify and impossible to attest objectively, and because practical and political involvements make it generally difficult to modify the course of action. This makes decisionmakers hesitant and ready to justify on-going technological trends, rather than to challenge them.

Competition First

SAT implies that the so-called "external costs and benefits", which are omitted in current business calculations, should be taken into account in the appraisal of new technologies. The question then arises, who is supposed to bear the costs when it comes to international competition? Any internalization of additional items raises the question of distorting the established pattern of international exchange of goods.

The results and recommendations of a SAT study may well be considered as an intrusion into national economic policy or as a device by foreign competitors to reduce the competitiveness of national firms. It may be opposed because of the inherent risk of technological lag, leading to economic dependence and political subordination. Overall anarchy in technological developments can thus be justified on the grounds that each country is compelled to let technology proliferate freely for the sake of its national survival.

PROSPECTS OF SAT

It should be recalled that the fundamental rationale of SAT is that, henceforward, various social groups other than the actual initiators and proponents of a technology are claiming the right to be heard in decisions concerning the future application and diffusion of a technology. There are several basic characteristics that distinguish the SAT approach, making it potentially far reaching in shaping the decisionmaking process:

- SAT must be conducted in a systemic way, i.e., the problem under consideration must be studied as a system, as a dynamic whole whose components are defined both per se and through their interrelationships.

- Its central part is a systematic inventory of the possible impacts on society, both direct and indirect, over the short and long terms.

- The crucial phase is the attempt to evaluate all of these impacts including, as well as the usual technical and economic ones, the impacts on individuals, social groups, social structures, the environment, and value systems.

- Not only promoters and interested parties must be taken into account. In particular, the options and sociopolitical weights of those social groups which have previously been considered as external to the decisionmaking process must be brought into the analysis of impacts and especially into the formulation of policy.

- The expected outcome of genuine SAT is to present an array of coherent action options to the decisionmaker.

The assessment thus implies a multidisciplinary approach allowing for a simultaneous tracing of the pathways between technological developments and societal impacts. It can be performed only as a multi-iterative feedback process where the analysis of a technological development interacts with the generation of new knowledge about its impacts and with needs for action options likely to optimize the societal benefits of the course of action decided upon.

With such a wide range of phenomena, variables and relationships to be considered, SAT is of necessity a particularly complex matter and an extremely extensive and demanding activity that is hardly possible without incessant evaluation of the states of society that relate social and economic developments to technological change.

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Experience in Multinational Forecasting of Science and Technology Advance

V. Glushkov, G. Dobrov, V. Maksimenko, and Y. Ershov

INTRODUCTION

One example of international research related to Systems Assessment of New Technology (SANT) is the joint work currently being performed by the Council for Mutual Economic Assistance (CMEA) countries in the area of scientific and technological forecasting. The present paper will provide an overview of this work and of some of the lessons learned by the participants.

Underlying all of these cooperative research efforts is the complex program for further improvement in cooperation and development of socioeconomic integration of CMEA member states, which suggests that CMEA members will strive jointly for further development of scientific and technological forecasts for 10 to 15 years or even more, according to agreed subjects and common methodological principles and organizational forms, drawing also upon the results of national forecasts.

Cooperation of the CMEA member states in the sphere of scientific and technological forecasting is carried out by means of studies of theoretical and methodological problems of forecasting, planning science, and technological progress, as well as the preparation of forecasts on multilateral and bilateral bases.

A task of vital importance has been to increase the effectiveness of the joint forecast investigations and of the application of their results to practical planning and management. Experience with such investigations has demonstrated the necessity for integrated methodologies and for the expedient solution of problems of effective application of scientific and technological forecasts to practical planning and management of national economies in socialist states.

METHODOLOGIES FOR JOINT RESEARCH

Joint work on the preparation of a draft of common methods for forecasting scientific technological progress in the CMEA member states, within the framework of multilateral cooperation, began in 1972. The joint forecasting methods that were developed with major contributions from such countries as the USSR, the German Democratic Republic, and Czechoslovakia, and from an international group of scientists at the Institute of Management Problems of the Academy of Sciences of the USSR, are an essential theoretical and practical outcome of development in the sphere of scientific and technological forecasting [1]. These methods represent one of the first internationally developed methodological documents in the sphere of the forecasting and planning of scientific and technological progress.

By definition, scientific and technological forecasting implies a multivariant hypothesis about the feasible results and pathways of scientific and technological development in the future as well as about the resources and organizational arrangements required for their achievement.

When forecasting processes of scientific and technological development, one should obtain detailed answers to the following questions:

1. What is the desired standard for meeting specific social needs relevant to the area of scientific and technological progress being forecast?

2. What results of science and technology development in the future--and in what fields--are desired and necessary for the required standard to be achieved?

3. What are the feasible results of scientific and technological development in the future in the foregoing fields of science and technology?

4. What scientific and technological problems may arise from disagreement between the necessary and the feasible results of scientific and technological progress?

5. What are the possible methods of achieving the desired and necessary results?

6. How long will it take to cover each of the possible methods?

7. What is the degree of certainty of covering each of the possible methods?

8. How much manpower, equipment, and financial resources will be necessary for covering each of the possible methods?

9. What type of organizational arrangements would facilitate the results with respect to one method or another?

10. What are the most rational methods?

The following stages of scientific and technological forecasting can be singled out, all of which are considered to be necessary: analytical, research, programmatic, and organizational.

The analytical stage of a forecast should offer answers to questions 1 and 2. The outcome of this stage consists of determining the desired state of development of the object being forecasted, on a national level and in comparison with the international level.

The intention of the research stage is to supply answers to questions 3 and 4. The effect of the research stage consists of determining goals for future scientific and technological development in the form of a definite problem of science and technology, or a number of such problems, to be solved during the period under prognostication.

The purpose of the programmatic stage consists of giving answers to questions 5, 6, and 7. The programmatic stage of the forecast provides feasible ways of reaching goals for scientific and technological progress.

The organizational stage is aimed at supplying answers to questions 8, 9, and 10. The organizational stage determines feasible variants of the resource distribution and organizational and technical arrangements on a national and international level, which are necessary for achieving the objectives of future scientific and technological development. Also it describes a number of rational (with relation to time, certainty of realization by a specified time, necessary resources, and organizational arrangements) ways of achieving the objectives of future scientific and technological development.

In order to combine all of these stages into a single entity, a method is used that provides their succession as stages of development of a complex forecast comprising information about objectives, ways, and resources of scientific and technological progress in future. The essence of this method is described in [2].

At the beginning, a particular problem of science and technology (ST), or a group of such problems, is formulated as the result of a thorough analysis of the state and trends of development of a branch of science or engineering, as well as through the use of both group and individual expert assessments. These problems may arise either from advanced social and economic needs, which can be determined by long-term forecasting of processes in the national economy and the social sphere, or deduced from possibilities for future scientific and technological progress.

The selected problem or problems are then evaluated by specialists who, in principle, could personally undertake to find a solution. Every expert specifies the scientific and technological conditions under which he would be able to proceed with solving the problem in question. Moreover, the expert estimates the time, finances, equipment, manpower resources, and organizational and economic requirements necessary for the successful solution of the problem. Each of the conditions specified by the expert is evaluated as a sub-problem in accordance with the above procedure by other specialists, and so forth.

This process can be presented as a hierarchical tree structure (Figure 1). Movement down the tree ceases under two circumstances: either when specialists begin specifying conditions whose satisfaction does not necessitate undertaking research and development, or when none of the specialists engaged in assessing a certain event are able to specify scientific and technical conditions sufficient for its achievement.

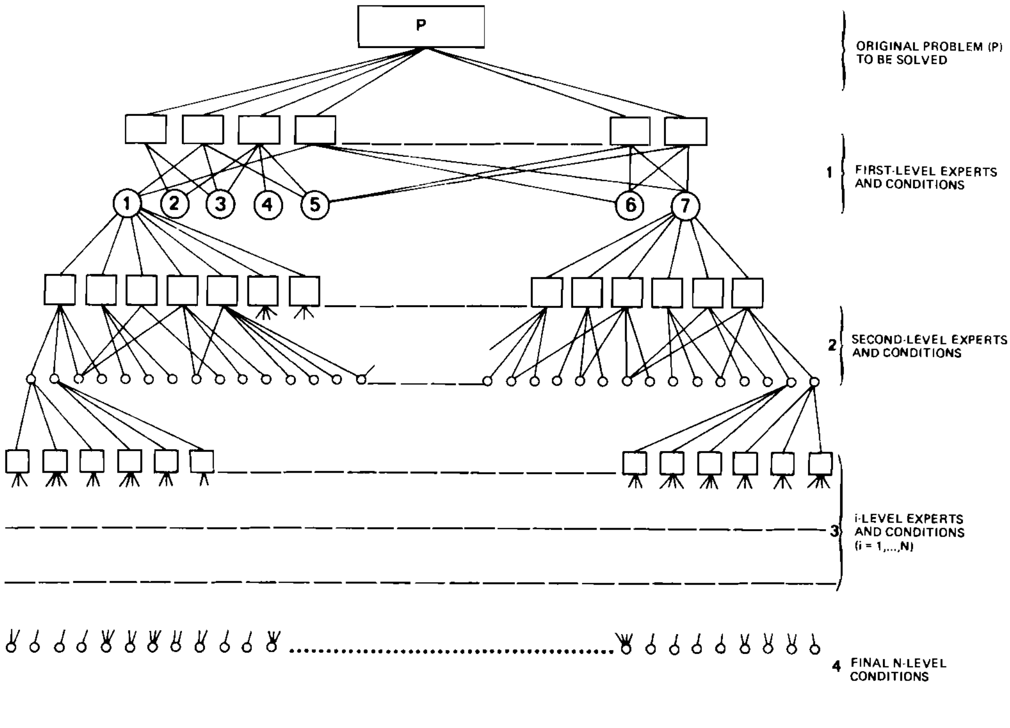

Figure 1. The forecasting chart.

When the hierarchical structure is completed, different methods of solving the original (top-level) problem are analyzed in regard to the required time, manpower, equipment, and financial resources, as well as organizational and economic requirements and other criteria.

Once the hierarchical structure has been developed, it is treated as a dynamic system that must, from time to time, be updated with new information from specialists. This information may be obtained both from the research work conducted by the expert himself, from data on the achievements of ST in his own country and abroad.

A system of uninterrupted ST forecasting is created on the basis of the foregoing method. The possibility arises for effective and creative international cooperation of representatives of different branches of knowledge, as well as for the expedient use of achievements in the fundamental sciences. The creation and functioning of such a system is based on the use of an electronic computer.

IMPLEMENTATION OF METHODS

In December 1974, the Methodology of Joint Prognostication of Science and Technological Progress Carried Out by the CMEA Member States Concerned were approved and recommended for employment [1]. Since then much has been done to create organizational conditions for putting these into methods of joint forecasting practice.

A seminar on national and technological forecasting was first held for specialists from the CMEA member states in November 1975 in Kiev. This meeting helped to improve scientific standards of forecasting by presenting information concerning the significance of various methodological problems in improving the process of forecasting and planning ST. As a consequence of this seminar, more stable scientific and technical contacts among cooperating organizations of the CMEA member states were established and several bilateral and multilateral projects of cooperation in the sphere of scientific and technological forecasting were designed. When developing joint forecasts, the CMEA member states envisage an orientation and interrelation of task assignments that will focus on major prospects of mutual interest and strengthen connections with forecasts in the various overlapping sciences and related branches of engineering and economics. Developing forecasts requires the cooperation of scientists and highly trained specialists from science and production institutions, management and planning agencies, and information-servicing bodies.

For the purpose of making forecasts in various branches of ST in 1976, recommendations were made with respect to the practical implementation of joint forecasting methods. These recommendations specify how special organizations and agencies within

CMEA should proceed in developing scientific and technological forecasts covering one or several branches of ST. The forecasting procedure comprises six stages, built around a framework of scientific coordination sessions for representatives from the organizing countries and participating states. All stages of forecasting should be realized by applying, in the best possible way, previously prepared national and international forecasts of development in the fields of science under study and related fields.

Stage 1. Preparation for the First (Organizational) Scientific Coordination Session

The organizing country appoints a head organization (HO) responsible for developing a joint forecast. The participating countries appoint cooperating organizations (COs) to participate in development of the forecast. The HO works out a preliminary concept for the forecast, prepares a preliminary program for forecast development and sends it to the COs in the participating countries.

The preliminary concept of the forecast covers: formulation of the goal for joint forecasting with respect to the chosen problem; determination of a forecasting object (i.e., the phenomenon to be forecast, formulation of the chief directions for scientific and technological progress in the field under prognostication and definition of particular tasks whose fulfillment would provide for successful development of their respective main directions, recommendation of ways of organizational forms of forecast development, and specification of the main stages of forecast designing. The preliminary concept of the forecast and the preliminary program of forecast development are specified, taking into consideration the specific character, condition, and development of each participating country.

Stage 2. The First (Organizational) Scientific Coordination Session (SCS)

Proceeding from information obtained from the COs of the participating states as well as from the preliminary concept of the forecast and preliminary program of the forecast development, the HO, with the participation of representatives of the COs, formulates at the SCS, a joint concept of the forecast and a joint program of forecast development. The program of forecast development supplies instructions for specific tasks for the COs of participating states.

Participants in the first SCS agree on methods for analyzing the state and trends of the forecasting object and for designing a system of goals of scientific and technological development and methods of reaching them, having due regard to the specific character of the forecasting object and the specific conditions under which the forecast is being developed. They also agree on the design of questionnaires ("tables of expert assessments") and corresponding procedures for expert opinion enquiry and analysis.

The composition of the final forecasting document (which will eventually be prepared) is specified with reference to the precise nature of this forecast, and this outline is turned over to the Working Group for cooperation in the sphere of scientific and technological prognostication and also the corresponding CMEA agencies and member states.

Stage 3. Preparations for the Second SCS

The COs carry out analysis of the state and trends of the forecasting object on a national level and compare them with those in other highly developed industrial countries. Analysis and comparison are carried out only with reference to the most essential scientific and technological indices and technical and economic characteristics; basic results of fundamental and applied research, greatly affecting the state and prospects for the development of the forecasting object; basic technical and economic indices of technical aids and processes already put into production or planned to be put into production; quotes for labor expenditure, output per unit production area and per unit time, equipment performance, reliability of the output, etc. In this case, the level of research with respect to the problem under prognostication is characterized as regards the specialization developed within the country and also the attained and planned level of accomplished research. Analysis of the state and trends of the development of the forecasting object on an international level is made by the HO.

Experts are questioned in order to assemble a system of goals for the development of the forecasting object and ways of reaching them. This draft system is made up by the HO as a hierarchical structure, the upper level of which presents goals corresponding to the social and economic needs of the CMEA member states and of the whole socialist community.

According to their specific idea and character, the various goals forming a part of the above-mentioned system of goals can be formulated as a "development goal" or a "goal of creation".

A development goal is formulated as a country-wide desired state for the forecasting object, not defined as a specific result but only indicated as a process, course, or trend of change in the object, e.g., raising the productivity of labor, improving the quality of goods, or increasing reliability and effectiveness.

A goal of creation is formulated as a specific desired achievement that may be realized at a definite point in time, e.g., the creation of a specific engineering system or the introduction of a certain production process.

With respect to each of the goals belonging to the upper level of the hierarchy, the HO forms a complex of planned interrelated types of work--research and development (R&D), design and technology work, introduction of technical aids and production processes--whose completion is directed towards reaching this goal and, with respect to each kind of work, suitable countries are appointed for its fulfillment and a date for completion is fixed.

The draft of the system of goals and methods for reaching them should involve data on the most significant technological and economic indices with respect to the forecasting object.

Stage 4. The Second SCS

The agreed proposals for the system of goals and ways of reaching them are discussed and worked out. Agreement is reached on the method to be used in specifying organizational and economic conditions needed for realization of the system of goals and also on the necessary list of candidate organizational and economic characteristics. The detailed content of the final forecasting document, whose general composition was specified during the first SCS, is decided, and the procedure for its preparation is agreed upon.

Stage 5. Preparations for the Third (Final) SCS

Proposals for organizational and economic conditions that make possible the realization of the system of goals are produced for both the national and the international levels. A draft of the final forecasting document is prepared by the HO.

Stage 6. The Third (Final) SCS

This corrects the final forecasting document and obtains agreement about it. The final forecasting document is then sent to the appropriate CMEA agencies and member states.

LESSONS LEARNED IN JOINT WORK TO DATE

The experience gained during this year's practical use of the Joint Methodology has showed its effectiveness as well as a set of sophisticated problems which still need to be solved.

The problem of a common understanding of the aims and possibilities of forecasting is fundamental for the success of the Joint Methodology. The main line of our discussions is to meet managerial needs for a system of data on forecasts, assessments, evaluations, alternatives, and potential capabilities.

The lessons of our experience have proved the importance of including, in the analytical process, decisionmakers on different levels and scientists and engineers involved in joint work, as well as specialists with permanently improving professional skills in forecasting methodology.

One of the main preconditions for success in multinational forecasting is to take into account the specific interests and priorities of each member country. This is especially important at the stage of common choice among the final forecasting hypotheses [3].

The number of variants and development possibilities studied in the course of a forecasting project may be extremely high. No more than a manageable number (usually not exceeding 5 to 7) of the more-promising variants must be selected for inclusion in the final forecast documentation. The authorities responsible for decisions on the forecasts and for using them in drawing up long-term plans will, in turn, confine their choice to only parts of these variants.

In selecting the variants, the forecasters are guided by the data contained in the "component data sheets" and also by the data in the forecasting document, and by the following basic groups of criteria: forecast reliability criteria, policy criteria, technical and economic criteria, and criteria of systematic coherence.

Forecast Reliability Criteria

These criteria are used in estimating the quality of the postulated hypotheses, with a view to eliminating doubtful or ill-founded proposals. Here reliance should be placed on the experience and intuition of highly qualified specialists, and at the same time, in taking decisions involving the choice of possible innovations, use should be made of established, formalized methods or risk evaluation.

Policy Criteria

This is a wide class, which takes into account the social structure, the internal and external policy of both the country concerned and of the socialist community as a whole, and the ideology and other factors expressing the attitude of the state and society in question toward science and the national goals that science is called upon to attain.

A specific category in this class of criteria is that of "priority", i.e., the level of achievement relative to other countries. Such criteria are given urgency, and not solely by sufficiently serious considerations of economics and defense. The problem is that no single country can maintain world priority in the full range of scientific and technical areas being forecast. It is therefore necessary that the strategic doctrine of each country recognize those areas of ST in which it does not deliberately set itself goals for achieving world priority but is content to rely mainly on the application of international scientific and technical experience. This does not mean that there is no longer any need to master the latest achievements of world science, for success in using their results inevitably presupposes the presence in the country of a sufficiently high level of scientific potential.

It is essential to know even more positively the areas in which achievement of world priority is recognized as a national goal. In developing such areas, a considerably higher level of risk is accepted, i.e., a lower probability factor for the individual forecasting variants and a substantially higher capital intensivity for the R&D programs to be carried out.

Scientific and technological cooperation considerably increases the scope for advancement in all the CMEA member countries along the most promising avenues of scientific and technological progess.

Technical and Economic Selection Criteria

For selection of the economically most appropriate alternatives for future scientific and technological development, the following procedure may be recommended:

- A classification of technical and economic criteria is prepared (volume of capital investment, expected effect, technical level to be achieved, time required for fulfillment of the forecasting hypothesis, and the production conditions needed for this, etc.).

- For each group of criteria, an estimate is made (in points), in a specially compiled estimation table, of the possible state of the forecasting variant. For example, for the criterion "Expected impact of innovations on the technical level of production", the table might show the following possible states and the corresponding estimates in points: simple enlargement of the range of goods, 1; higher-quality production or alteration of the existing technology, 2; elimination of a shortage of that type of product, 3; and so on.

- A group of specialists evaluates, in accordance with the classification table, each of the forecasting variants proposed for consideration.

- A comparison is made of the total points awarded to each variant, and a decision is made, on the basis of specific financial and production possibilities, as to which variants shall be put forward for further consideration.

One very promising approach is evaluation of the variants in terms of the progressiveness of capital investment, by which is meant the ratio of the growth of labor productivity (or volume of production) caused by scientific and technical progress to the growth of that indicator, attributable to increased capitalization.

Criteria of Systematic Coherence

These criteria for estimation of the possibilities of future scientific and technological development are based on consideration of the needs of all the structural components of the science-technology-production system.

In this context, the prospects for new avenues of fundamental research are assessed according to the degree of impact they may have on other sciences. The more substantial the changes expected in other fields, the higher the estimate of prospects for research in the area under review. The prospects for a specific orientation of applied research are assessed according to its position and role in the science-technology-production system.

In the process of analyzing foreseeable situations as regards scientific and technological development, various possible methods of encouraging the clarification of obscurities, reducing vagueness of judgment, etc. are considered in turn. The requirements for planning and organizing a complex system of research, methods of applying it, and the production technology measures necessary for the achievement of progress in the field being forecasted are classified in four main groups, corresponding to the different levels of decisionmaking and the organizational forms of their implementation:

- The first class of possible decisions is the organization of intensive work on theoretical problems and of a purposeful search for new principles for the solution of particular scientific and technical problems.

- The second class occurs in situations where fundamental ideas and theoretical knowledge are available but ideas regarding their application are absent or inadequate. In this case, requirements and proposals are formulated for organizing and carrying out purposeful R&D work, and an indication is given of the people and organizations who are closest to success in solving such problems.

- In the third class, the reason why the experts very often make too low an estimate of the probability of rapid introduction of a series of new ideas is that not enough experience has been gained in working these ideas out technologically, and that resources are lacking for their application on an economically justified scale for mass or series production. In this case it is necessary to work out specific proposals for the accelerated development of a special experimental and technological base or for acquiring technological documentation, for example, by way of scientific and technical assistance between CMEA member countries.

If the results of the analysis of any body of scientific and technical work show that it has a sufficiently high degree of promise, a basic condition for prompt and successful attainment of the proposed goals is the creation of the organizational and economic prerequisites for the speediest performance of work on the realization of the new possibilities in practical production.

- In the fourth class of decisions are usually involved an indication of possible sources of additional investment, the adoption of measures to stimulate the process of creating new technical resources, such as an active policy in the field of standardization and harmonization, the use of the possibilities of multilateral and bilateral scientific and technical cooperation between states, and expanded trade in patents and licences.

At the organizational stage of forecasting, as developed within CMEA, it is especially important to indicate, for each "key event", the group of countries taking part in its performance, and also the planned level of the participation of each of them.

Key Event 1

The country possesses the necessary capacity and is interested in solving the problem (attaining the sub-goal) independently, exchanging information with all participants in the program and making the results available to all participating countries in any form compatible with the goals of the program.

Key Event 2

The country has some of the necessary scientific and technical potential, is interested, and agrees to act as the leading organization in order to solve the problem together with other participants in the program.

Key Event 3

The country has some of the necessary potential and is interested in cooperating with other participants under the guidance of the leading organization in solving the problem.

Key Event 4

The country lacks the necessary scientific and technical potential to play a part in solving the problem but is interested in receiving information on the progress made and experience gained in solving the problem, and is counting on the possibility of using the results in accordance with the division of labor within the framework of the program and its goals.

Studies on the problem of applying forecasting results in planning are aimed at working out scientific principles for the development of long-range programs for the integration technology problems of mutual interest within CMEA. These cover the complete cycle of research, development, and the adoption of new technology in production. Investigations on improving methods of joint forecasting along these lines are concentrated on working out the following problems:

- Uniting balance-methods of planning with methods of programmatic forecasting;

- Development and inclusion of long-range norms for expenditure, effectiveness, and technological coefficients of the technology under prognostication;

- Development of procedures for the continuous use of forecasts in planning.

When the forecast is developed, it is necessary to focus special attention on the effects that future scientific and technological developments may have on economic phenomena. The factor of scientific and technological progress has a pronounced effect on practically all other forecast components, greatly affecting the development of various branches of the national economy. It is necessary, therefore, to take into account the effect of scientific and technological development on the complicated relationships among different branches of the economy, the possibility of the advent of advanced production processes, and the possible development of new branches of technology and production based on the achievements of science.

The successful solution of these tasks is associated, in many respects, with the making of a system of long-range norms and suggestions controlling their comparability with the level of scientific and technological progress [4]. Data on long-range norms should be considered in the optimization of planned output

Technology Assessment for International and National Technology Transfer

H. Maier

This paper deals with the role of Systems Assessment of New Technology (SANT) in the solution of one of the most important problems for the economy and social policy in the socialist countries; namely, the transfer of research and development (R&D) results to production. At present, this is one of the weakest parts in the chain that connects science and technology (ST) with production [1]. When looking at different studies of this problem, one would get the impression that the ability of the economy to absorb new results of ST is unlimited, and it is therefore only necessary to apply new results of R&D to production immediately. However, in practice, things are not that easy. The ability of the economy to utilize new technologies is, in concrete situations, not unlimited. This is the reason for the importance of the assessment of new technologies from the point of view of the needs of members in society, and from the points of view of social goals and economic efficiency. The assessment of new technologies must assist us in answering the following questions: What, when, and to what extent should the results of ST be used in production [2]?

At the very beginning of every assessment of technologies, it should be understood that it is impossible to apply all the results of R&D within a certain time range to production. It is therefore incorrect to think that only those results of ST that have already been applied in production are of value. For the USA, for example, it has been shown in different studies that only 0.15 percent of the new ideas for creating new products lead to commercial profits. Similarly, the number of completed R&D projects that have led to new products with commercial profits are not more than 6 percent of all completed R&D work [3].

This does not mean that the ideas which do not end up with profitable products are completely without value. However, we still do not know very much about the complicated mechanisms through which intermediate ideas are of future benefit to ST.

There are two main economic reasons for the high standard for assessing results of ST for application in production. The first is that, in most cases, the exploitation of R&D needs additional investment, which can be several thousand times the expenditure spent for the development of the idea. This means that, in highly developed countries, new technologies can be applied only if existing machinery are replaced. Such replacement makes economic sense only if the increased efficiency of the new machinery or technology substantially exceeds the economic loss resulting from the replacement of the old machinery and if there is little likelihood that another, even better, solution for the problem will be available in the near future. If new methods are introduced too early, it might well be possible that no more resources for the realization of an even better solution might be available at a later time.

A second problem that limits the application of new results of ST derives from the changing economic risk associated with any introduction of new technologies. With the introduction of new methods, there is not only an increased possibility for higher economic efficiency, but there is also an increased risk. We therefore need a well-balanced mix among existing, slightly advanced, and completely new technologies if the economic development of our society is not to be confronted with unacceptable risks. International experience has shown that miscalculations of the costs and timing of the introduction of new products are usually higher, the more recent the new technologies are. This observation should never be forgotten in any realistic assessment of new technologies. It could be said that, if all possible technologies were attempted without realistic assessment immediately after their introduction, there would be a complete breakdown of the economy [4]. The choice of the technologies to be used for production, the determination of the appropriate time to introduce new ones, and the selection of diversification speed are therefore crucial problems for the scientific-technical policy for single companies and for the country as a whole. It is important to distinguish between three levels of the assessment of a technology: first, the time-span between the proof of its technical feasibility and the beginning of the R&D work for economic use; second, the time-span between the beginning of the R&D work and the first economic use of this new technology; and third, the time-span between the first economic use and the perfection and wide distribution of this new technology.

At present, according to Mansfield, the first part is approximately twice as long as the second. The important shortening of the time-span for the practical use of new results of ST in real production in the last 75 years is mainly due to the shortening of the first part. The second part consists of a sequence of different phases that are very complicated to coordinate. The most time-consuming step here is the construction of pilot plants and prototypes, which needs, on average, one-half of the time for this second part, while applied research and the production of the necessary tools, instruments, and machinery each uses approximately 30 percent of the time. When adding up these different parts of the second phase, one must take into account the fact that they can sometimes overlap. A well-deliberated coordination of all activities could lead to an important shortening of the time-span of this second part. A good international example is the development and application of the high-speed mass-transportation system of the Shinkansen project in Japan, which was the topic of an important IIASA conference in 1977.

Various studies have established numerical values for the different stages; they are presented in Table 1.

Table 1. Average values of the time needed for assessment.*

Industry	Time of the Phase (Years)			
	Applied Research	Technical** Development	Start of Production	Process in all (Years
Electro-industry	2.9 ± 1.4	2.9 ± 1.4	1.9 ± 1.1	7.7 ± 2.2
Production of tool-making machines	1.9 ± 0.9	1.9 ± 1.3	2.3 ± 1.2	6.1 ± 1.8
Machine Production	1.9 ± 0.9	1.9 ± 1.2	1.6 ± 0.9	5.4 ± 1.7

*Calculated as the median of the sample and standard deviation.
**Production and testing from prototypes, final production, and governmental examination.

Systems analysis is better than all existing one-dimensional methods in dealing with the complexity of the decisionmaking process for the introduction of new technologies for production. For this, one must distinguish between the following types of situations for decisionmaking which need different methods for research.

First, cases that have a commensurable need but different expenditures. Here one can choose, without major problems and with the help of cost criteria, the variant with the best cost/benefit relation. This relatively rare case is sometimes supposed to be the only existing one, which causes the principal danger of an improper investment in the process of decisionmaking.

Second, variants that need the same expenditure but that lead to different results. These different results must be assessed on the different levels of the decisionmaking process and made comparable.

Third, cases in which it is not possible to compare expenditure and benefit. These must be assessed individually, and they must be compared on the different levels of decisionmaking.

Only the first (very rare) type of decision situations can be handled with the one-dimensional method of decisionmaking. Situations of the second and third types can only be handled with the help of systems analysis. This fact shows that, in most cases, one must rely on systems analysis, which will take the following elements into account:

- The expenditure compared to the existing products and methods. It is very necessary to distinguish between the efforts needed to realize the first results of R&D and the expected expenditure that will be necessary in a second phase after the initial output of products that must compete with others.
- Parameters for the quality and performance of the new products or methods compared with those of the existing products or methods with respect to social, productive, or individual needs.
- The time of the technological availability of the results of R&D, estimation of the time of the practical introduction, the degree of novelty, and the technological perspectives of the result of R&D.
- Estimation of the speed of diffusion of the new technology and its ultimate share of the total possible production.
- Estimation of the export potential of this product or method and its present level of import.
- Estimation of the impact of the new methods on working conditions, mainly the diminution of heavy or unpleasant work.
- Estimation of the overall social benefit or harm of the new product or production method, e.g., for the quality of the human environment.

The main problem is to deal with system interrelationships between these components and to get the necessary information on it [5]. Since development projects usually do not violate objective laws of nature, certain parameters of quality or performance can be obtained in any case after a certain time and with high costs. Among costs and effectiveness, time of introduction, and the social benefit of ST, there are usually contradictory tendencies that must be taken into account and estimated very carefully. For example, it is possible to reach a given level of quality or performance sooner if more resources are allocated to it, or at a given expenditure to reach certain results in ST if the requirements for quality or performance overlap. It is very dangerous in the assessment of results or in the guidelines for ST to look only at different components of effectiveness, since it is possible, in most cases, to reach a good performance in one component at the expense of others. All of this shows the outstanding importance of systems analysis for an effective assessment of specific developments in ST.

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Possibilities and Needs for Data Bases for SANT with Special Reference to the International Level

W. Rauch

STATEMENT OF THE QUESTION

"It is a sad sign of materialism of the present time, that official authorities and the statistical bureaus are more interested to know how many pigs, sheep, oxen and calves are eaten per capita by the people than to know how much mental food they consume, total or individual" [1].* This statement by Alexander von Öttingen, written in 1882, is still valid to a certain degree and causes many problems in some scientific disciplines, e.g., in the field of technology assessment (TA). In this paper I intend to point out some of the problems, needs, and possibilities that exist for the creation of data bases for Systems Assessment of New Technology (SANT), and, in view of the specific emphasis of this workshop, to pay particular attention to some of its international aspects.

As used here, the term "data base" (also, "data bank") means "a collection of factual information, particularly when deposited in the memory core of a computer (stored), organized or structured by categories pertinent to a problem area, and accessible to be called out or consulted" [2].

The concept of SANT that I use in this paper is based on the report which G.M. Dobrov presented to IIASA in February 1977 [3]. According to this report, SANT is the general rubric that encompasses applied systems analysis in the fields of technology forecasting (TF), technology assessment (TA), etc., not only for technical innovations as such, but also organizational and managerial innovations.

"In other words, SANT...is a *system of data* for the basing of ST [science and technology] management decisions" [3].

This sentence points out very clearly that SANT has at least two aspects: the systematic (what the kind and direction of interaction is in the system of science and technology; what the causal

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*"Es ist ein trauriges Zeichen der materialistischen Richtung unserer Zeit, dass den amtlichen Organen und statistischen Büreaus mehr daran gelegen ist zue erfahren wie viele Schweine und Schaafe, Ochsen und Kälber per Kopf der Bevölkerung verzehrt werden, als wieviel geistige Nahrung solider Art die Gesamtheit oder alle Einzelnen verbrauchen".

influence of ST is in the socioeconomic environment as a whole and vice versa; etc.) and the data aspect (what kind of data are already available; what kind of data are needed; etc.). These two aspects are very closely related and reinforce each other. Dobrov concentrated on the systematic aspect of SANT [3]. In my presentation I shall stress the data aspect.

A distinction of three successively more encompassing levels of technological development, namely "technological changes", "technological advance", and "technological progress", as presented for systems analysis, appears helpful for structuring the existing and needed data.

At the level of management of technological changes (management of processes of research, development, and transfer of innovation) data are needed on:

- Scientific potential (input to the Research and Development (R&D) system: skilled manpower, scientific ideas, financial means, etc.);

- Structure of R&D (specific characteristics of the system at the international, national, or institutional level; number of research units, staff with different educational levels within research institutions, etc.);

- Scientific productivity (output of the R&D system: technological possibilities, scientific books and reports, etc.).

At the level of management of technological advance (management of the processes of forming and implementing ST policy, including the acquisition, distribution, and utilization of technological results), there will be an additional need for data about the socioeconomic environment, industry, agriculture, medicine, culture, politics, education, etc. Such data are needed to study the broad range of effects of using newly emerging technological possibilities and, finally, to establish data on effectiveness.

At the level of management of technological progress (social management of technological progress in the largest possible sense) there will be a further need for data and concepts about criteria, priorities, needs, and values.

It can be seen from Table 1 that a very wide range of data is, to a certain degree, relevant to SANT. On the other hand, every area of SANT has the problem of noncomparability and often even the absence of the necessary initial data.

What kind of service could an institute such as IIASA provide to find solutions to this problem?

Table 1. Types of data relevant to SANT.

<table>
<tr><td colspan="3">TECHNOLOGICAL PROGRESS</td></tr>
<tr><td colspan="2">Technological Advance</td><td rowspan="3">General
Policy
and
Economy</td></tr>
<tr><td>Technological Change</td><td rowspan="2">Science
and
Technology
Policy</td></tr>
<tr><td>RESEARCH AND
DEVELOPMENT
(PRODUCTIVITY)</td></tr>
<tr><td><u>Data on</u>
The Scientific Potential (INPUT-Data)
The R&D System (STRUCTURE Data)
Scientific Productivity (OUTPUT Data)</td><td><u>Data on</u>
The Socioeconomic System and the Environment</td><td><u>Data on</u>
Needs
Values
Criteria
Priorities</td></tr>
</table>

The preamble to the Charter of the International Institute for Applied Systems Analysis asserts "that science and technology, if wisely directed, can benefit all mankind" [4]. If we believe this, it would seem appropriate that IIASA should be strongly engaged in questions of SANT. I think that this is undoubtedly true for the systematic aspect, but perhaps only partly true for its data aspect.

For at least three important reasons, IIASA cannot collect all relevant statistical data on a regular basis. The first stems from the multidisciplinary nature of the Institute. The field of data relevant to its research is almost as wide as the scope of data relevent to SANT. The idea that the science-technology-management (STM) approach combines professional data (engineering, biological, ecological, etc.) provided by the WELMM (water-energy-land-materials-manpower) approach with more general economic, organizational, legal, sociopsychological, and "systems of SANT" data, makes it practically impossible to collect all relevant data.

Secondly, the international nature of IIASA makes it undesirable to limit its research to certain regions or countries. Collecting country-specific or region-specific data could make sense for individual case studies, but certainly not for a long-term IIASA research plan.

Thirdly, IIASA consists mainly of scientists of different scientific and cultural backgrounds who stay for relatively short periods. If everybody were forced to use a special IIASA data bank, it would cause an excessive effort for all staff members.

This third reason for IIASA not to compile a data bank for SANT guides us to a possibly useful function for IIASA in the field of data for SANT; IIASA could act as a clearinghouse for SANT's data sources. This function could easily be adopted and maintained with the participation of scientists, visiting scholars, and interested workshop participants who work in their home institutions with data bases containing data relevant to SANT. As a secondary effect, this could help to maintain the scientific relations between IIASA and scientists who have been at the Institute in Laxenburg. Such a computerized "statistical sources for SANT" list could be updated very easily and thus also serve indirectly as a guide to all recent work in this field. This could help to bring the scientific community in this field very close together.

Such a computerized list could act also as an important module for a Computer Assisted Group Interaction (CAGI), in particular for CAITR (Computer Assistance for International Team Research), a concept proposed to IIASA in March 1977 by R.H. Randolph [5].

The basic requirement for such an interaction of experts via computer is a high degree of "transparency" of the scientific community involved: everyone linked to CAITR should know as much as possible about the scientific background of his partner so as to avoid misunderstanding and misinterpretations of the computer dialogue. One important part here is the knowledge of the data used by the members of CAITR. If some data are computer readable, a very easy exchange could be performed via this network.

DATA ON RESEARCH AND DEVELOPMENT

The problem of data, their sampling, their comparability, etc., is not merely a problem of SANT; it is also the problem of statistics in every scientific discipline. Hence we must focus especially on data relevant to the level of technological change. This level is the basis for the management of ST and is of fundamental importance for every SANT, even though only one aspect of their data bases. This focus on technological change data means that we are mainly interested in the measurement of scientific and technical activities; that is, data on R&D, by which we understand (according to the Frascati Manual [6]) that the "Research and experimental development comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications" [6].

In order to be more specific, I present some examples of data in this field in Table 2. Suggestions for some of the

Table 2. Important data for SANT on the level of technological change.

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1. INPUT to R&D (Potential)

    1.1 Ideas

    1.2 Manpower employed by R&D
        1.2.1 Classification by occupation (researchers, technicians, other supporting staff, etc.)
        1.2.2 Classification by formal qualification (holders of university degrees, of diplomas, etc.)
        1.2.3 ...

    1.3 R&D Expenditure
        1.3.1 Intramural R&D expenditure (wages, material, administrative expenses, etc.)
        1.3.2 Extramural flows of funds (support from and payments to other organizations)
        1.3.3 National aggregates and motives concerning performers and sources of R&D funds (gross domestic expenditure on R&D, supports from countries, etc.)
        1.3.4 ...

    1.4 Other

2. STRUCTURE of R&D (Classifications for structuring input and output data)

    2.1 Institutional classifications
        2.1.1 Classification by sector (business enterprises sector, general government, etc.)
        2.1.2 Classification by subsector (further subdivision of 2.1.1)
        2.1.3 ...

    2.2 Functional classification of R&D
        2.2.1 Classification by product field (e.g., the Standard International Trade Classification)
        2.2.2 Classification by field of science
        2.2.3 Classification by socioeconomic objectives (according to the purpose of each activity)
        2.2.4 ...

    2.3 Other

3. OUTPUT of R&D (Results)

    3.1 Physical products
        3.1.1 Data on new, better, cheaper products
        3.1.2 Data on new, better, cheaper technologies
        3.1.3 ...

    3.2 Intellectual products
        3.2.1 Published books and articles
        3.2.2 Citation statistics
        3.2.3 Patent statistics
        3.2.4 ...

        these have feedback on "ideas" (1.1)

    3.3 Other

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categories have been obtained from the Organisation for Economic Co-operation and Development (OECD) and the United Nations Educational, Scientific and Cultural Organization (UNESCO) publications [6,7].

This systematic structure is very preliminary and comprises, as mentioned above, only the level of technological change. Note that the proposed structure represents a circle (or, if you prefer, a spiral); the output of each research activity could be used as the input (in the form of new ideas) for other research work.

The classification of the "output" sector of R&D is much vaguer than the "input" sector, because "Statistics of R&D are presently limited to inputs" [7].

Data from all the categories mentioned above are important to all of the different elements of SANT. They are the input and output of TF; they are the main basis for TA; they help to describe alternative technologies; they provide the basis for the evaluation of research; and they are the main scientific indicators. However, as can be seen from the three-level model (Table 2), data for R&D alone are insufficient for SANT.

All elements of SANT need very careful consideration of data from the second and third levels described earlier; data about the socioeconomic and environmental sphere and data in the context of needs and values, criteria and priorities.

To explain in greater detail the kind of influence between these three levels relevant to SANT, I give examples of some types of influences in the 3 × 3 matrix in Table 3.

I think this matrix is neither new nor surprising. However, it shows that the main part of SANT lies not in the field of technology but in its interaction with natural and social systems. If we look at the international aspects of SANT, we should pay attention to international mechanisms in the system of needs and values, economy and environment. As far as I know, not very much analytical work has yet been done in this field.

In all of the different categories mentioned before, data of three kinds are possible and necessary: primary, secondary and transformed.* This subdivision is, of course, not rigorous, and the categories merge into each other to a certain degree.

Primary data are statistical data and figures from scientific papers: usually short-time series, unsystematic samples, etc.

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*Presentation method taken from Mesarovic, M. and E. Pestel, *Mankind at the Turning Point: The Second Report of the Club of Rome*, Dutton, New York (1974), pp. 32-55 (Chapter 4: Multilevel Model of World System).

Table 3. Types of influences relevant to SANT.

	INFLUENCING FACTOR		
THING INFLUENCED	Technology	Socioeconomic and Environment Area	The Area of Needs and Values
Technology	Crucial inventions; internal mechanisms of	Economic constraints; laws of nature	Needs as the main motive for technology; values as the main control of the direction of technological progress
Socioeconomic and Environmental Area	New technologies create new economic possibilities; new social problems and environmental side effects	Internal mechanisms of society and technology	Needs as the main motive for the economy; values as its main control
The Area of Needs and Values	New possibilities create new "needs" and can cause changes in the rank-order of values	Basic human needs; needs created by the society; values of a specific society	Crucial ideas and attitudes; philosophy and internal mechanisms in ethics and philosophy

Secondary data are data resulting from regular statistical sampling on a wide range. They are collected methodically and published at regular times, and some of them are stored in computerized data banks.

Transformed data, like primary data, are weaker than secondary data and are usually contained in books and articles. These are data resulting from transformative work done with secondary and/or primary data. Transformed data contain expert estimations, forecasts, results from simulations, etc.

The discussion on primary data is about new ideas and new concepts: new correlations, a new context for old ideas. The discussion on secondary data is of needs and possibilities in the field of statistical sampling. The discussion on transformed data is on research: Which direction does science and development take at present? Where do we need additional research work?, etc.

To find information on secondary data, statistical data bases are mainly relevant. Bibliographical data bases are of important interest for finding preliminary and transformed data, which are often contained in scientific books and journal articles.

SPECIAL PROBLEMS AT THE INTERNATIONAL LEVEL

Most scientists active in the field of TA feel there is a serious lack of statistics in this area, especially at the international level. There are also urgent needs for data to assist policymakers in the field of SANT.

In principle, there are two possible ways to cope with this situation: either to try to improve (unite, coordinate, integrate, etc.) existing statistics and information systems or to establish completely new statistics and information systems for ST policy.

The advantages of the first approach seem clear. Under certain conditions it could be easier and could be realized with less opposition than the second approach and has therefore a much higher probability of success. However, it is not clear whether this approach would be generally successful. Are existing statistics such that improving on them will satisfy our needs? Is it possible to make existing ST statistics comparable at an international level?

The second approach, implementation of a completely new integrated information system, would encounter much opposition. This opposition could arise from one or more of the four powerful sources that exist institutionally in the field of ST policy: the scientists, the "professionals" (entrepreneurs, users, practitioners), the politicians, and the administrators.

These four groups sometimes have conflicting interests, which hinder ST policy and which could also defeat new information systems. This has often happened at the national level and is even more likely to hinder international realization of new ST information systems. It is most likely that any assessment of an information system at an international level would encounter the same problems as international cooperation and ST strategies. For these reasons the following suggestions have been made at the Ad Hoc Meeting of Experts on the Measurement of International Technology Flows of the Economic Commission for Europe [8]: "A far reaching examination should be made of the *institutional* (organizational) barriers to establishing a quasi 'data bank', i.e., an information system computerized and integrated in international dimensions:

- although for many years UNESCO, CES [Conference of European Statisticians] and ECE have conducted invaluable activities, *coordination* is still not complete, not even among the United Nations institutions (UNESCO, UNCTAD, UNIDO, FAO, ECOSOC, ECE, etc.);

- cooperation among the United Nations institutions and the European regional economic groupings (CMEA, EEC, EFTA) in the area of information supply has progressed slowly, while all information 'sub-systems' require an exchange of information and its institutionalization;

- it might also be asked whether or not it is justified to build up an information-switching system at *regional* (ECE) level, considering that the flow of S & T is taking place with *global dimensions* (for example, the EEC has 'associated' with non-European developing countries);

- what prevents the rapid and efficient establishment and operation of the different *national* information systems? To what extent is this related to the social order of goals and values of different countries; to what extent are the shortcomings and difficulties of a statistical or organizational nature (lack of data, methodological problems, structural organization weaknesses, lack of information willingness, barriers to information abilities, etc.)?

- will a switching system in which the national 'focal points' do not have administrative authority be able to operate at all for how will it be able to enforce a reliable supply of data?"

In addition to these barriers for establishing data banks for SANT there is one important structural problem. On one hand, we are speaking about the lack of information in the field of ST statistics; on the other, we all are aware of the ever-increasing information flood and information crisis. The only possible way out of this dilemma is the precise description of the data in which decisionmakers in the SANT field are really interested. If statistical sampling on a wide (perhaps international) level is begun before there is international consensus about the necessary kind of data, even more problems will be encountered. We therefore need both an international consensus on ST policy strategy to establish appropriate statistics as well as good international ST statistics to establish valuable ST policy strategies. This problem can only be solved by a step-by-step improvement of both systems. At the international level, this will require much time, because these problems have not yet been solved even at a regional level: "Since even the outlines of a new S & T policy strategy have only just begun to take shape in the ECE region, it cannot be supposed that this is rooted in the shortcomings of existing statistics; in other words, it is not probable that development of new statistics would lead to a new S & T policy" [9].

After this short analysis of possible ways to improve ST statistics at the international level, it seems much more useful to improve existing statistics than to establish completely new statistics and information systems.

Despite all these problems, many large international information systems exist, even if most of them have not yet been fully established or are only being developed; CMEA, EC, IMF, GATT, UNCTAD, OECD, UNESCO, and UNIDO, among others, are active in this field. In the present situation, therefore, an integration of all existing international information systems from the point of view of SANT seems very promising. Such a system could be established most realistically with the assistance of a United Nations organization already active in this field (such as UNESCO or UNIDO) and should also try to integrate the international information systems of non-United Nations organizations.

As examples of these information systems, the following section presents a preliminary list of computerized data bases relevant to SANT on an international level, and in place of the bibliography, a short guide to guides to international statistics.

A LISTING OF INTERNATIONAL COMPUTERIZED DATA BANKS

The most important trend in international statistics is the increased use of computers, mainly in the United Nations system. The use of computers allows the production of reports and time series with a rapidity that would be almost impossible without the use of fast machines mainly for international statistics. In the last part of this paper I present a short review of Computerized International Statistics (CIS). The information is based mainly on the *Directory of International Statistics* of the United Nations [10]. In the list are the 40 data bases of the organizations of the United Nations system (see Annex). For SANT in a narrow sense (R&D, technological change), mainly the Data Bases UNESCO-1 and ECA-6 are of important interest. For the use of SANT on a higher level, all computerized statistics can be important to a certain degree.

Some efforts have already been made to coordinate these activities of different organizations of the United Nations system. In 1967, the Administrative Committee on Coordination (ACC) created the Sub-committee on Statistical Activities, and in 1970 the Inter-Organization Board for Information Systems and Related Activities (IOB). These two organizations are concerned with even higher integration of existing computerized data bases.

A list of the major guides to statistical sources is given in Annex 2. It contains only guides that refer to international data and are less than three years old.

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Annex 1. Data Bases of the UN System

ORGANIZATION AND NAME OF DATA BASE	TYPE AND DESCRIPTION OF STATISTICS CONTAINED IN THE DATA BASE
UNITED NATIONS STATISTICAL OFFICE	
1. UNSO-1 *United Nations Demographic Data Base*	Statistics on geographic location, personal and cultural characteristics, fertility, vital statistics and migration of the population.
2. UNSO-2 *System of National Accounts (SNA) and System of Material Product Balances (MPS) (NAMAST)*	National accounts data organized according to the United Nations System of National Accounts (SNA) for market economies and according to the System of Material Product Balances (MPS) for the centrally planned economies.
3. UNSO-3 *Commodity Production Statistics* (ICPDATA)	Statistics on the outputs of industries engaged in mining, manufacturing, production, and distribution of electricity, gas, and water, major divisions 2, 3, and 4 respectively of the International Standard Industrial Classification of All Economic Activities (ISIC).
4. UNSO-4 *World Energy Supplies System* (WORLDENERGY)	Statistics on production, imports, exports, bunkers, stocks and capacity of solid and liquid fuels, gases and electricity.
5. UNSO-5 *External Trade Statistics* (STAPPPPPPCCCC)	Statistics on external trade by commodities and by trading partners.
6. UNSO-6 *Indexes of Industrial Production*	Country indexes of industrial production.
7. UNSO-7 *General Industrial Statistics* (UNINDUST)	Statistics on major items of data for industries engaged in mining, manufacturing, production, and distribution of electricity, gas and water, major divisions 2, 3, and 4 respectively, of ISIC.
ECONOMIC COMMISSION FOR EUROPE	
8. ECE-1 *Standardized Input-Output Tables* (1059A)	Standardized input-output tables in 22 industries.

ECONOMIC AND SOCIAL COMMISSION FOR ASIA AND THE PACIFIC 9. ESCAP-1 *International Trade Statistics of the ESCAP Region* (1962-1968/70510-401)	Imports, exports and re-exports of commodities by partner country.
ECONOMIC COMMISSION FOR AFRICA 10. ECA-1 *Agriculture, Forestry and Fishing*	Statistics on production, crops, livestock, forestry and fishing, and means of production.
11. ECA-2 *Survey of Economic Conditions in Africa*	Agricultural products, country per capita, etc.
12. ECA-3 *Trade*	Statistics on external trade by commodities and by trading partners.
13. ECA-4 *Prices and Finance*	Statistics on money and banking, exchange and interest rates and balance of payments, price indexes.
14. ECA-5 *Communications*	Statistics on passenger and freight transportation by road, rail, water, and air; radio, television communication; and postal traffic.
15. ECA-6 *Demographic and Social Statistics*	Statistics on geographic location and personal characteristics of the population, population projections, economically active population, education and teacher training, health manpower and facilities.
16. ECA-7 *Industrial Production*	Statistics on industries engaged in mining, manufacturing, production and distribution of electricity, gas and water, and construction, major divisions 2, 3, 4, and 5 respectively of ISIC.
17. ECA-8 *National Accounts*	National accounts data organized according to SNA.
18. ECA-9 *NAC "Data for Economic Surveys"*	National accounts data, distributions and growth rates, implicit price indexes for broad expenditure groups and by kind of activity.
19. ECA-10 *Quarterly Files*	Statistics on prices, international liquidity and money supply, international seaborne shipping, trade, and industrial production.
20. ECA-11 *Public Finance*	Statistics on general government expenditures and receipts, central government public debt, etc.

INTERNATIONAL LABOUR ORGANISATION 21. ILO-1 *Labour Force Estimates and Projections 1950-1985*	Labor force by sex and age.
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS 22. FAO-1 *Interlinked Computer Storage and Processing System of Food and Agricultural Commodity Data* (ICS)	Statistics on total population, supply and utilization statistics on crops, crop products, livestock numbers and products, means of production (fertilizers, pesticides, farm machinery), fish catches and products and forestry.
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION 23. UNESCO-1 *UNESCO Statistical Data Bank* (UNESCOSTATBA)	Statistics on educational characteristics, system, institutions, and teachers, enrollment, and educational expenditure.
INTERNATIONAL CIVIL AVIATION ORGANIZATION 24. ICAO-1 *Civil Aviation Statistics* (SA-TR1)	Statistics on system totals of traffic for scheduled international airlines.
25. ICAO-2 *Civil Aviation Statistics* (SA-TR2)	Statistics on country totals of traffic for scheduled domestic and international airlines.
26. ICAO-3 *Civil Aviation Statistics* (SA-FD)	Statistics on revenues, expenses and assets and liabilities for scheduled international airlines.
27. ICAO-4 *Civil Aviation Statistics* (SA-FL)	Fleet data for international scheduled airlines including number, capacity and utilization of aircraft.
28. ICAO-5 *Civil Aviation Statistics* (SA-PE)	Statistics on number and expenditure for personnel employed by international scheduled airlines.
29. ICAO-6 *Civil Aviation Statistics* (SA-TF)	Statistics on traffic flowing between city points in international scheduled airline service.
30. ICAO-7 *Civil Aviation Statistics* (AP-TR)	Statistics on traffic arriving and departing from world's principal international airports.
31. ICAO-8 *Civil Aviation Statistics* (CA-AR)	Statistics on number of aircraft registered by type of aircraft.

WORLD HEALTH ORGANIZATION 32. WHO-1 *General Mortality Data Base* (DB)	Statistics on causes of death, cancer mortality, morbidity from infectious diseases. health manpower and hospital facilities.
INTERNATIONAL MONETARY FUND 33. IMF-1 *Money and Banking* (FMB)	Statistics on international finance and liquidity, monetary statistics and accounts of monetary institutions, accounts of other financial institutions, statistics relating to money and banking services, other monetary statistics.
34. IMF-2 *General Statistics* (FGNSTAT)	Statistics on population and employment, industry, trade, finance, and prices.
35. IMF-3 *IMF Account* (FNDACCT)	Statistics on the Fund's accounts.
36. IMF-4 *Reserves* (FCABLES)	Statistics on member country reserves.
37. IMF-5 *Trade* (FDOTMST)	Statistics on the direction of trade.
38. IMF-6 *Balance of Payments* (FBOPMST)	Statistics on the balance of payments, including goods and services, unrequited transfers and capital flows.
39. IMF-7 *Government Finance*	Disaggregated major elements of government finance data including reserves, expenditures, and financing of the deficit/surplus.
GENERAL AGREEMENT ON TARIFFS AND TRADE 40. GATT-1 *Tariff and Trade Data File* (Basic file)	Customs duty rates and imports by selected country according to tariff lines.

Annex 2. Some Recent Major Guides To International Statistical Sources

1. United Nations, Department of Economic and Social Affairs, Statistical Office, *Directory of International Statistics*, New York, 1975.

   Guide to international statistics of all different kinds; concentrates on statistics of international organizations.

2. Wassermann, P., and J. Paskar, *Statistics Sources*, Gale Research Company, The Book Tower, Detroit, Michigan, 1974.

   Guide to data on industrial, business, social, educational, financial and other topics for the United States and internationally; emphasis on United States data.

3. United Nations Educational, Scientific and Cultural Organization (UNESCO), Division of Statistics on Science and Technology, Office of Statistics, *Annotated Accessions List of Studies and Reports in the Field of Science Statistics*, Paris, 1976.

   Guide to national statistics relating to scientific and technical manpower and the financing of research and experimental development and related activities.

4. United Nations Educational, Scientific and Cultural Organization (UNESCO), Office of Statistics, *Publications of the Office of Statistics, 1974-76*, Paris.

   Guide to all publications published by the UNESCO Office of Statistics, that is, mainly statistics and reports about science and technology.

5. *Statistics--Asia and Australasia; Statistics--Africa; Statistics--America; Statistics--Europe*, by Joan M. Harvey, 1976, CBD Research Ltd., Beckenham, Kent, England, 1976.

   Guides to organizations and publications providing statistical information on economic, social and market research for all countries in Asia, Australasia and Oceania; Africa; North, Central, and South America; Western and Eastern Europe.

6. OECD/DSTI "Science Resources" Unit, *Sciences Resources/Newsletter*, Paris, 1977.

Periodic Newsletter on sicence resources issued under the responsibility of the OECD Secretariat (bi-annual).

7. International Labour Office, *ILO Catalogue of Publications in Print - 1977*, Geneva.

Guide to international statistics from the ILO on labor, wages, employment, etc.

8. Unipub, *World Guide to Technical Information and Documentation Services*, New York, New York, 1975.

Guide to 476 international and national centers and institutions in major subject fields are included.

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G. Dobrov (IIASA), *The Dynamics and Management of Technological Development as an Object for Applied Systems Analysis*

K. Chen (USA) and L. Zacher (Poland), *Toward Effective International Technology Assessments*

O. Helmer (IIASA), *Selection of Technologies for International Assessments*

National Experience: Chairmen, M. Tribus (USA) and H. Maier (GDR)

M. Cetron (USA), *Quantitative Aids for Research Management Decisions in the Future Environment*

H. Maier (GDR), *Technology Assessment as an Important Precondition for the Effective Applications of R&D Results in Production*

L. Gérardin (France), *To Take into Account or to Assume*

V. Pokrovsky (USSR), *Development of Applied Methods of Systems Analysis in Estimating the Efficiency of New Technologies*

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W. Hahn (USA), *Technology Assessment and Science Policy*

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International Problems: Chairman, K. Chen (USA)

F. Hetman (OECD), *Social Assessment of Technology and Some of Its International Aspects*

V. Glushkov, (USSR), G. Dobrov, (IIASA), V. Maksimenko (USSR), and Y. Ershov (USSR), *CMEA Experience in Multinational Forecasting of Science and Technology Advance*

A. Straszak (IIASA), *International Assessment of Large-Scale Undertakings - Lessons from IIASA Case Studies*

J. Menkes (USA), *Technology Assessment - Theory and Practice (Be Realistic, Demand the Impossible)*

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Methodology and Modelling: Chairman, P. Jones (UK)

L. Kantorovich, A.G. Kruglikov, V.I. Zhiyanov (all USSR), *Models for Analysis of the Dynamics of Technological Development*

C. Marchetti (IIASA), *A Post-Mortem Technology Assessment of the Spinning Wheel: The Last Thousand Years*

P. M'Pherson (IIASA), *Energy, Growth and Technological Change*

M. Tribus (USA), *Transfer of R&D Results into Production*

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